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ENGLISH RAILROAD TRACK.

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American engineers, as a whole, are, I think, little conversant with the details of English railroad practice, and some few years ago I contemplated the preparation of an extended paper, or series of papers, on this subject, thinking that in this country, where railroads have reached a greater extent than in any other part of the world, such a paper would be of interest to the profession. The first part of this paper, on "Railroad Legislation in England," was published in *Engineering News*, August 1st, 1885; but in proceeding with the succeeding part I found, like many another man who has started out to accomplish something on a large scale, that I had undertaken too much, and had neither the time nor the material necessary for the work; and soon realized that the paper could not be prepared on the intended scale without considerable time being spent in personal investigation. This [illegible]ng impracticable, I abandoned so comprehensive a project and devoted my attention to the details of track matters; and while the English system does not commend itself, as a type, to many engineers outside of England, yet there are

some points which may be learned from it, and some details which might well be adopted as improvements on the average American practice. The details given are mostly obtained from official sources, and I wish to express my obligations to the engineers of a number of railroads in the United Kingdom, for courtesies received in the way of drawings, specifications and general information.

The standard type of English track consists of heavy rails carried in cast-iron chairs, which are attached to timber cross-ties. The rails are of two sections, viz.: "Double-headed" and "bull-headed;" the former section has two heads of similar form, connected by a web, and is intended to be reversible, although in practice this reversing is very rarely carried out; the latter section is simply a non-reversible double-headed rail, the disadvantages of reversing being recognized, and the lower head made only large enough to give a hold to the wooden key, or wedge, which is driven between the jaw of the chair and the web of the rail. These chairs, which weigh from 25 to 56 pounds each, give a wide bearing on the ties, to which they are attached by trenails, spikes or bolts. The ballast is generally broken stone, frequently with gravel boxing; broken slag from the iron furnaces is sometimes used, also burnt clay occasionally. Split switches are invariably used, the stub switch being unknown (except, perhaps, for contractors' tracks). Complete systems of semaphore signals, on the latest and most approved plans, are in general use, together with interlocking systems to a great extent; the block system of operation is generally adopted. Three features of railroad practice are: 1st. Heavy and careful construction; 2d. Complete equipment for safe operation; 3d. Care in operation and maintenance. Of course, accidents do happen, and would happen whatever care and precaution might be exercised, but they are far more rare than in this country (taking into account the difference of mileage). In fact, as far as safety of operation is concerned, I think the English railroads rank the highest in the world. This, of course, is without regard to the question of economy of construction, which is too little considered in England. The track is substantial and safe, but requires a large amount of unnecessary metal, and is unreasonably and unnecessarily expensive, a fact which renders it especially undesirable for introduction into the colonies and other new countries. The standard gauge is 4 feet 8½ inches, but the main line of the Great Western Railway is still 7-foot gauge, with a third rail for standard gauge rolling stock. Narrow gauges are

very rare. A space of six feet is left between the lines of double track roads.

The heads of English rails are very different from those of American rails. The majority of the older rails had rounded heads, formed by a succession of curves from the web to the top. The 82-pound double-headed rail of the North Eastern Railway is an example; also the 76-pound double-headed steel rail designed for the New South Wales Government Railways; the dimensions of the latter were as follows: height, 5½ inches; width of heads, 2½ inches; thickness of web, ⅜-inch; beginning at the middle of the rail the web was ¾-inch thick for 0.92-inch, then it widened out by a curve of 0.55-inch radius, followed by a short tangent at an angle of about 30 degrees for nearly half an inch, then a curve of 0.59-inch, forming the side of the head and running into the curve of 5½ inches radius which formed the top table. Other sections, such as the Great Northern Railway, 82 pounds, and the Great Western Railway, 86 pounds, have the sides of the head curved to a radius of about the width of the head, with top corners of large radius, about ¾-inch. A section much in favor now has vertical sides, with sharp top curves; the 85-pound rail of the Midland Railway is a good sample of this section; it is 2⅝ inches wide, radius of top table 5⅜ inches, radius of top corners, ½-inch, vertical part of side, ⅞-inch deep. The heads of the 79-pound flange rail and 75-pound bull-headed rail of the Great Northern Railway (Ireland) are 2½ inches wide, radius of top table, 10 inches; radius of top corners, ½-inch; vertical portion, $\frac{7}{16}$-inch deep; radius of bottom corner, ⅜-inch. I think it would be interesting to know how the wear of English rails and wheels compares with the wear of American rails and wheels. For comparative sections and dimensions of rails of different countries I would refer to an article of mine on "Rail Sections," published in the *National Car Builder*, New York, August, 1885.

Flange rails (or Vignoles rails, as they are universally termed in Europe), are not favorably considered for English railroads, although they have been tried on all classes of roads. Lines which were formerly laid with these rails have been relaid with the bull-headed rail, which is now the standard English rail section. It is a little difficult to understand this, when it is considered that the flange rail has been adopted as the standard section in all other parts of the world. The English system of double-headed rails in heavy chairs will undoubtedly make a very solid and durable track; but it is, in my opinion, too solid, contain-

ing much unnecessary metal and consequently entailing unnecesary expense. If this section is adopted, the rails must be supported in chairs, and, of course, these chairs do some good in distributing the weight over a large area of the tie, but this does not warrant the placing of 25 to 56 pounds of cast-iron at each end of every tie. To strike at the root of the matter, however, I believe the double-headed rail (and in referring to this section I also include the bull-headed section) to be, in the light of modern experience, unscientific and unnecessary. The original idea was brilliant—to make one rail do the work and last the life of two; this was plausible, but in practice it was not successful, for the weight of the traffic caused the lower head to be indented at its seat in the chair, so that riding was very rough when this head was put into service. Different methods of obviating this defect were tried; in some cases, as on the North Eastern Railway (Plate LX), wooden cushions were placed between the rail and the chair; in other cases the rail was suspended in the chair, being supported by the under side of the rail-head resting on the jaw of the chair. This latter method was adopted originally on the London and North Western Railway, and is still in use to some extent in India, and a somewhat similar plan was suggested by Mr. W. Bridges Adams, the inventor of the fish-plate. The result of these endeavors, however, may be guessed from the general adoption of the bull-headed, non-reversible rail.

Even if it is conceded that the English type of track, as now in use, is safe and substantial, and adapted to the requirements of traffic on English roads, it was surely a most ill-advised proceeding to introduce it in the colonies. Yet, in India, it was extensively introduced, and in 1876 a track was designed by Mr. John Fowler, M. Inst. C. E., for the New South Wales Government Railways, which consisted of 76-pound double-headed steel rails in 26-pound chairs. In this way the colonies were likely to be overwhelmed with capital expenditure, and it is easy to see what a much greater extent of country might have been developed and made productive by the use of a track lighter and less costly, but equally efficient for traffic requirements. With a flange rail there would be 52 pounds of cast-iron (chairs) per yard saved, or 91 520 pounds per mile, while a 65 or 70-pound rail would have been amply heavy enough, especially with the English system of fastenings; in fact, a 71½-pound flange rail was designed for this same system. The flange rail, however, is now extensively used in all the colonies, and will probably

supersede the double-headed rail entirely; this latter form of rail is still in use in India, and has even been introduced into South America by English engineers, generally in conjunction with cast-iron "pot" sleepers. The following are the weights of some English rails for the colonies, etc.: Queensland, 41¼ pounds per yard flange rails for a gauge of 3 feet 6 inches; South Australia, 50 and 61 pounds per yard flange rails for gauges of 3 feet 6 inches and 5 feet 3 inches respectively; India, from 41¼ pounds per yard flange rails for 3 feet 3⅜ inches gauge, to 75 pounds for 5 feet 6 inches gauge, also double-headed rails of about 70 and 75 pounds per yard for 5 feet 6 inches gauge; South America, 58, 67 and 70 pounds per yard flange rails, and 50 pounds per yard bull-headed rails (resting on wooden cushions in cast-iron chairs) for a gauge of 5 feet 6 inches. Had the "rail and chair" type of track been generally adopted, the colonies would have built the railroads for posterity, reaping little practical benefit during the youth of the country. Had the promoters of an American transcontinental line waited until they could build a road of the standard of the Pennsylvania or the New York Central, I fear the Panama Railroad would be in a condition to put down a double track of 100-pound rails with cast-iron chairs, and perhaps there might be some American enterprise in the canal scheme. In this country the tracks are adapted to the requirements of the roads, and although there are many lines with too light a track, yet there are many excellent tracks on the busy Eastern roads, and the improvement of the tracks is following the increase in traffic, which is true economy. I would like to note the fact that weight is not the only essential for rails of busy roads; good design and good manufacture are equally necessary, and as an instance of the necessity of good design, I may say that the Panama Railroad was originally laid with 56-pound rails (four inches high); a heavier rail was considered necessary a few years ago, and the weight was increased to 70 pounds, but the extra metal was principally used in thickening the web, giving but a slight increase in stiffness.

In Ireland the flange rail is very generally used, and is very favorably spoken of by the engineers of some of the principal lines, although the bull-headed rail is stated to be advantageous on curves, as giving better results in maintenance and efficiency. Some rail sections and details of the track of Irish railroads will be found on the accompanying plates; and I desire especially to call attention to the fastenings, which are

decided improvements upon the universal but inefficient spike fastening of American practice.

In my correspondence with the engineers of English lines I have been particular to ask for their views on the respective merits of double-headed and flange rails, and the replies have been very unfavorable to the latter, the points made being that they will not stand under heavy traffic and high speed.

Mr. Forrest, Secretary of the Institution of Civil Engineers, says: "The Vignoles pattern rail was used a good deal by contractors who made cheap railways, but it has been universally condemned and taken up, as the fastenings soon worked loose, and the rails would not keep to gauge. It has the further disadvantage that a bad rail is not so easily changed as one fixed in chairs. The Vignoles rail, as used in this country (England), weighed from 60 to 75 pounds per linear yard; the Metropolitan, of course, more.* It was from 4½ to 5 inches high, and from 4 to 5 inches broad in the bottom flange, according to the fancies of the constructing engineers. This form of rail is used generally on the Continent, but most continental engineers are believed to prefer the double-headed rail with chairs, and are only prevented from using it by reason of the extra expense.† The railways on the Continent have the advantage of hard-wood sleepers, which hold the rail fastenings better than the pine sleepers universally used in England."

Mr. Conner, formerly engineer of the Isle of Wight Railway, a line on which 70-pound flange rails, 4½ inches high, with 5½-inch base, have been replaced by 78-pound double-headed rails, writes as follows: "The rails are reversible, but are not turned over, experience showing they are then rough to travel over and more liable to break. I strongly recommend bull-headed rails, and for heavy traffic know of none better than those of the London and North Western Railway, which are 90 pounds per yard. * * * Spikes are not reliable for flange rails."

Mr. Owen, engineer of the Great Western Railway, writes as follows:

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* The flange rail used on the Metropolitan Railway, London, was 4.2 inches high, with a base 6¾ inches wide; it has, however, been replaced with a bull-headed section.

† I cannot think that Mr. Forrest is correct in this remark, as the flange rail is almost universally adopted on the Continent, even on State railway systems, where a little extra cost would not prevent the adoption of a specially good form of rail. Many of the double-headed sections used on the Continent have been of bad and clumsy design, resembling an hour-glass in section. Heavy flange rails are the most modern type adopted and approved, which is a step in the right direction.

"Flange rails are very seldom used, only on country lines with four or five trains a day; they cut into pine sleepers and are very troublesome to maintain. The Hammersmith and City line* has been relaid with chairs and rails. The double-head is not now laid, all relaying is bull-head."

Mr. Bayley, Engineer-in-Chief of the Great Southern and Western Railway (Ireland), on which 74-pound flange rails are used, writes: "Consider bull-head best where traffic is heavy."

Mr. Keeling, engineer of the Severn and Wye and Severn Bridge Railway, a road which has several grades of 1 in 40, and one of 1 in 30 followed by 1 in 31, the two aggregating about 2½ miles in length, with some sharp curves, writes as follows: "We found that the flange or Vignoles rail was troublesome and expensive to maintain and keep in order on a line where the gradients are steep, curves sharp, and on which tank engines weighing (loaded) nearly 50 tons, are employed. We have therefore relaid the greatest portion of our line with the double-headed steel rail. I scarcely know any line of importance in England that continues to use the Vignoles rail on the main line."

Mr. Price, for fifteen years Chief Engineer of the Midland Great Western Railway (Ireland), writes as follows: "I believe as safe a road can be made of this (flange) rail as it is possible to make." He uses very efficient fastenings, as will be seen further on, and says: "This system is cheaper and safer than a double-headed rail or a bull-headed, but these latter are a little steadier and more silent. I do not believe in turning rails, so prefer a bull-headed to a double-headed rail." In another letter he says: "The general opinion is strongly in favor of flange rails, as being cheaper and nearly as steady as the double-head or bull-head."

Mr. Mills, Engineer-in-Chief of the Great Northern Railway (Ireland), writes as follows: "We use the bull-headed section on those parts of the line on which heavy curves and inclines exist, because this section of rail is more easily bent, and retains the curve better than the flange, and when laid in the cast-iron chairs and secured with the heavy fastenings, it forms a stronger road than the flange rail. The comparative cost is as 3 to 4, the chair road being the more costly." This road

* The Hammersmith and City line, which is a London suburban branch, was formerly laid with flange rails weighing 69 pounds per yard, having a base of 5½ inches, a height of 4½ inches, and a head 2½ inches wide.

has 139½ miles of double track, and 382½ miles of single track; total, 661½ miles, of which 106 miles are laid with the steel bull-headed rail.

Mr. Langley, Engineer-in-Chief of the Midland Railway, wrote as follows: "You have, I think, a great quantity of this (flange) section of rail in your country; doubtless, it was suitable for the light traffic, but as the loads have increased, I understand that you have suffered very much from broken rails. These breakages have, I think, been wrongly attributed to defective material, but are really the result of a defective design." In a later letter, replying to one in which I referred to the heavy and rapid traffic carried safely over the fine tracks of Eastern trunk lines, he wrote as follows: "Under the great velocities and heavy weights on the driving wheels of our engines, I think the road would be broken up in a few hours; in fact, in some cases it would not stand the passage of a single train."

This, of course, is largely a matter of prejudice, as the flange rail is used successfully for very heavy traffic, and in fact, this section, as a type, is now the standard section of the world, being a case of the survival of the fittest, improved upon by successive generations. On the other hand, it is pleasant to hear the general approval from Ireland, especially from Mr. James Price, the veteran railroad engineer, though even he says that flange rail track is "nearly" as steady as the double-head or bull-head; and even Mr. Sandberg, a strong advocate of the flange rail, says that speed has something to do with its non-adoption in England. So much testimony, from so many sources, must needs have some truth, and I think the explanation may be looked for in the locomotives and rolling stock. Although there are a large number of engines on the American plan, with a leading truck, and many cars on four and six-wheeled trucks, yet the majority of the equipment consists of passenger engines with a single pair of small leading wheels, with rigid axle (the total wheel-base being rigid); freight engines with six wheels, all coupled, and cars with two or three rigid axles. Such an equipment must undoubtedly be harder on the track than the "adjustable" American type of engines and cars.

The Pennsylvania Railroad has four sections of the London and North Western Railway standard track laid for experimental purposes. The rails weigh 90 pounds per yard, and two of the sections are laid with the steel cross-ties and chairs, while the other two are laid with wooden ties and cast-iron chairs. Some years ago, about ten miles of track on the

Boston and Worcester Railroad (now a part of the Boston and Albany system) were laid with 80-pound double-headed iron rails, carried in chairs weighing 28 pounds each. The rails were rolled at Worcester, Mass. The ties were spaced about 3 feet center to center. The joints were even and suspended; they were spliced with fish-plates and common bolts and nuts. The rails were secured by wooden keys, driven in solid and secured with a nail to each key. One defect of the track was the frequent breaking of the chairs. After ten years' service the track was relaid with flange rails.

An objection to the flange rail, and one which is strongly urged by its opponents, is that it cuts into the ties; this, however, can be easily prevented by the use of sole-plates, which are certainly cheaper than chairs. Mr. J. W. Post, of the Netherlands State Railroad Company, has had satisfactory results from the use of sole-plates with sharp teeth on the underside, which bite into the wood and prevent slipping; these plates are fastened by square-headed screws, which grip the flange of the rails.

The track accidents in this country may generally be attributed to bad condition of the road-bed, bad rails, inefficient fastenings and especially to the use of too light a rail. Mr. C. P. Sandberg, the designer of the 110-pound "Goliath" rail, shows in his paper on "Rail-Joints and Steel Rails" (Proceedings of the Institution of Civil Engineers, Vol. LXXXIV, 1886), that traffic which requires an 80 or 90-pound bull-headed rail in 40-pound chairs, would require a 100 or 110-pound flange rail. The 110-pound flange rail has already been adopted by some roads on the European continent, and large contracts for further supplies have recently been given out. The need of heavier rails is being recognized in this country, and in fact the more important lines are gradually introducing them.

If the English railroad companies or engineers would adopt a well-designed, heavy flange rail, and give it good joints and good fastenings, I think there can be little doubt that they would have a track fully as safe and efficient as with the present system, and costing no more for maintenance, but effecting a considerable saving in first cost, and built on more scientific principles. Mr. Sandberg, in a letter, states that speed has something to do with the rejection of the flange rail, but that if these rails are given the same chances as the others in weight, better results will be obtained for less money. As to the matter of speed,

however, there is traffic fast and heavy enough in this country, especially on the principal lines of the Eastern States, to prove the capabilities of the flange rail. The track should be designed for the traffic. Soleplates might be used to prevent the rail from cutting into the ties, and if there is fear of the track spreading, tie-rods might be put in to hold the rails together on curves or at other points.

Rail Tests.

The following are the tests given in the specifications of the railroads mentioned, and full-sized sections of the rails are shown on the accompanying sheet of rail sections. (Plate LXIII.)

Great Northern Railway.—(Steel rail, bull-headed section, 82 pounds per yard.) "A piece of rail 5 feet long shall be cut off and placed directly on solid iron bearings 3 feet 6 inches apart in the clear, fixed on a solid cast-iron block well bedded, and shall then receive successive blows from a weight of 1 120 pounds, falling from a height of 10 feet. Should the rail break before or under the third blow, or should it take a permanent set after the first blow, exceeding $1\frac{3}{4}$ inches, the whole of the parcel from which it has been selected will be rejected."

Midland Great Western Railway (Ireland).—(Steel rail, flange section, 79 pounds per yard.) "Each selected rail will be placed in the usual position, on bearings 3 feet 6 inches apart, and a weight of 18 tons will be applied on each rail at the center, between the bearings, and the deflection must not exceed $\frac{3}{4}$ of an inch after the weight has been applied for half an hour, and after the weight has been removed the permanent set must not exceed $\frac{1}{4}$ of an inch. The next test each rail will be subjected to is as follows: Placed in the usual position, on bearings 3 feet 6 inches apart, a ball weighing 18 hundred-weight (2 016 pounds) will be dropped upon each from a height of 8 feet, and each rail must bear two such blows without breaking and without deflecting more than 1 inch. The bearings on which the rails are to be tested to be of timber 12 inches square, 6 feet long and laid on solid hard ground. The rails to be held down to timbers by dog-spikes."

South Australian Government Railways.—(Steel rails, flange section, English manufacture).—The rails are to be placed upon supports 3 feet apart, must stand four blows of the drop test without breaking, and the dead-weight test must continue for ten minutes without causing permanent deflection. The bearings upon which the rails are to be tested must be formed with a radius of 12 inches, and form part of a block of cast-iron weighing not less than 2 tons. The block must be securely and properly bedded upon a solid foundation of concrete; the bottom of the "tupp," or falling weight, must be of the same form as the bearings of the block. The tests are as follows:

DROP TEST.

RAILS.	WEIGHT.	FALL.
41-pound.	784 pounds.	10 to 16 feet.
50- "	1 120 "	8 to 12 "
61- "	1 120 "	10 to 16 "

DEAD-WEIGHT TEST.

RAILS.	WEIGHT.	TIME.
41-pound.	10 tons.	10 minutes.
50- "	12 "	10 "
61- "	15 "	10 "

Should the inspecting engineer consider it desirable to have any check tests made in London at the public testing machine, the contractor must pay the cost of such test.

SPECIFICATIONS FOR RAILS.

The contractor is usually required to furnish rails which will stand certain tests, but is not bound to any special chemical properties of the material. The following are extracts from specifications in the writer's possession, and attention is called to the guarantee clauses.

Great Northern Railway.—The rails are to be of the bull-headed section, and an exact template will be furnished to the contractor. The rails must be made wholly of steel of the very best quality manufactured for rails by the Bessemer process. They are to be made of Nos. 2 and 3 hematite pig in equal quantities, to be remelted in cupolas, it being distinctly understood that neither Northamptonshire, Lincolnshire nor Cleveland pig will be allowed. The rails are to be made and rolled in England. Each rail shall be made from a single ingot, which shall be perfectly solid and regular in quality, and free from defects of every kind. The ingots to be subsequently thoroughly heated and reduced by being hammered to such an extent as may be deemed necessary by the company's engineer, before being rolled to the correct form. The rails must be sawn off perfectly square to the requisite length, and the ingots in all cases must be of ample length to insure a long crop being cut off, clear of the least appearance of scallops, at both ends of the rails; and should any imperfection in the quality, or unsoundness arising from gas cells, cold shuts, or otherwise, be apparent, either in the

ingots or during their subsequent treatment, such ingots or rails will be rejected and set aside as not being admissible under the contract. The rails when finished are to be in every respect perfectly sound and homogeneous, free from flaws, blisters and other defects, and perfectly straight. The rails are to weigh 82 pounds per yard, and none which either exceed or fall short of that weight by more than 1 pound will be accepted. The rails are to be cut to the exact length of 30 feet; the engineer, however, will receive for the contractor's convenience, a few lengths in even feet from 12 feet upwards, but together not exceeding 5 per cent. of the whole quantity. Each rail is to have at each end of it two holes, 1¼-inch by 1-inch, drilled truly to a template and gauge; no punching will be allowed. Each rail is to be marked G. N. R., with the initials of the makers, name of the works where they are manufactured, and the month and year when supplied. The contractor must provide the apparatus required for applying the specified test. The contractor is to deliver as directed by the engineer, in exchange, without charge to the company, a new rail of as good quality and make as those he delivers in the first instance, for every rail which, until twelve years after the date of the last delivery, shall become crushed, bruised, broken or seriously worn, whether the same be caused by ordinary or increased traffic, by the application of brakes, or by whatever cause (accident alone excepted); and should any rail supplied in lieu of an injured rail become injured as above described, the contractor shall continue to supply new rails in exchange as many times as the rails become injured in wear as above described, until the expiration of the term of the guarantee.

Midland Great Western Railway (Ireland).—The rails are to be rolled perfectly true and uniform throughout to the section shown (flange section; Plate LXIII), to be straight and out of twist, smooth on the surfaces, free from flaws or imperfections, and care must be taken that every rail is cooled in such a manner as to insure a proper temper. The weight to be 79 pounds per yard, none accepted weighing less than 78 pounds, and no allowance for any weighing more than 80 pounds per yard. Each rail is to have two oval holes punched at each end, as shown; these holes are to fit perfectly the fish-plates, when in their proper position, and no variation in either the position or size of holes exceeding $\frac{1}{32}$ of an inch will be allowed. Each rail is to be stamped on both sides of the web, near the middle (but not opposite), with the letters M. G. W. R., the maker's name and year of manufacture. The material out of which the rails are to be rolled, to be tough Bessemer steel of uniform character. The fish-plates are specified to be made true, uniform and perfect in every respect, of iron of a tough quality, capable of bearing a minimum tensile strain of 22 tons per square inch, and to stretch 10 per cent. in length before fracture. The plates to be cleanly punched from the inside, in pairs, alternately with square and round holes and to fit perfectly the sides of the rails.

South Australian Government Railways.—The rails are to be made from ingots large enough to make one or two rails, and the contractor must state whether they will be made by the Bessemer or Siemens' process. If by the Bessemer process, the ingots are to be made of the most approved mixture of hematite pig, all to be remelted in the air furnace before being subjected to the Bessemer process. If by the Siemens' process, the ingots are to be made of the most approved mixture of hematite pig, with the usual percentage of scrap steel added, and during the time the metal is in the furnace care must be taken to introduce such a mixture of spiegeleisen, etc., as shall insure an ingot of the hardest and toughest metal for the purposes of rail making. Each rail should be made from an ingot not less than 10 inches square at the smallest end, and of sufficient weight to allow all the unsound parts to be cut off each of the rails. The ingots are to be cogged into a perfectly sound and compact bloom. The fish-bolt holes, oval, are to be drilled. The rails are to be 30 feet long; those for the inner side of curves to be 29 feet 8 inches long. The manufacturer must ascertain and inform the inspector daily of the percentage of carbon in the rails, to enable him to report to the inspecting engineer. The fish-plates are to be rolled from first quality of Bessemer or Siemens' steel, suitable for the purpose and equal to the rails. The guarantee for rails and fish-plates is for a period of six years.

Fastenings.

One detail in which English track is superior to the average American track is that of the fastenings; and this detail is one of such vital importance for the efficiency and safety of the track, that it is worthy of very careful consideration. With the exception of a few cases, where some improved device has been adopted, such as the Bush interlocking-bolts on a part of the New York Central, the rails on American lines are held down only by the spikes, and for this reason accidents caused by the spreading of the track or overturning of the rails are very common. The ordinary spike cannot and does not hold under heavy traffic, and any one who cares to make a little observation can learn some very startling facts on the matter of rail fastenings.

The chairs for the double-headed rails in England are usually fastened to the ties by spikes, plain wooden trenails, compressed trenails (which expand and form a very tight fastening), or hollow trenails, which are first driven into the hole bored in the tie and then have a round spike driven into the hole. On the Great Eastern Railway the trenails are $6\frac{1}{4}$ inches long, $1\frac{1}{4}$ inches diameter for about 4 inches from the bottom, and then widen out to $1\frac{5}{8}$ inches diameter at the top. The spikes are round, $\frac{7}{8}$-inch diameter and $5\frac{1}{4}$ inches long under the head, which is hemispherical. The London and North Western Railway has its chairs

fastened by two plain spikes and two galvanized screw-spikes (three threads to the inch); the latter grip the chairs by means of wooden ferrules placed in the hole, through which the screws pass; the heads of these screw-spikes are hexagonal. The rails are secured in the chairs by wooden blocks, called "keys," driven horizontally between the web of the rail and the jaw of the chair; they are usually about $3\frac{1}{2}$ inches high by $2\frac{1}{2}$ inches wide and 7 inches long, sometimes taper and sometimes of uniform section. The London and North Western Railway uses a chair with four horizontal grooves in the face of the jaw, the ridges biting into the wooden key and preventing it from slacking back. The keys are driven, when possible, in the direction of the traffic, and are usually on the outside of the track; but some lines have them on the inside. Iron keys, made of a strip of iron coiled spirally, with a slight taper, to the form of the cross-section of an ordinary wood key, are used to a small extent.

But what is of more interest and importance to American engineers is the way in which the flange rails are fastened to the ties. The principal feature is the almost universal use of the fang-bolt, a very efficient form of attachment. These bolts are used at joints and at one or more intermediate points; there is a fang-nut at the under side of the tie, and the edges of this cut into the wood, so that the bolt can be screwed up from the top. In some cases the bolt passes through the flange of the rail, in other cases it holds the flange by means of a clip or crab; the former method is objectionable on account of expense and of trouble in adjustment. Screws, square (dog-headed) spikes and jagged spikes are used, in conjunction with the fang-bolts, at intermediate ties. On the Midland Great Western Railway (Ireland), ordinary bolts and nuts are used, but the nuts of the two bolts to each rail fit into a piece of channel iron on the underside of the tie, which prevents their turning; this arrangement is shown on one of the plates. With regard to this fastening Mr. Price writes as follows: "I fasten down with three pair of sole-plates to each pair of rails, one pair on each end and one pair on the center sleeper. The bolts fastening down are very large, for first-class railway $1\frac{1}{16}$-inch diameter, outside flange, or rather $\frac{1}{4}$-inch on flange, with washer on top gripping the rail. A road thus fastened has never been known to spread, even a derailed vehicle cannot burst it. The plates also prevent rail cutting into sleeper on outside edge round curves." Sole-plates are sometimes used at joints. For further details I refer to the accompanying notes of a number of railroads.

Joints.

The joints of English roads do not give so much trouble as those of American roads, and I think this is largely due to the security of the fastenings to the ties, especially the joint ties, and also to the wide spacing of the ties in the middle and close spacing at joints. Mr. Sand-

berg attributes this fact to the great weight of the rails. The joints are sometimes even and sometimes broken; sometimes supported, as on the Great Northern Railway, where two of the fish bolts pass through the jaw of a special joint-chair (Plate LXIII), but usually suspended. The ordinary joint consists of a pair of straight fish-plates, 18 inches long, with four bolts, the bolts having a square neck to prevent turning. The holes are generally spaced 4½ inches center to center; on the Lancashire and Yorkshire Railway the inner ones are 6 inches center to center, and the outer ones 4⅛ inches center to center, while on the Midland Great Western Railway (Ireland), the inner holes are 4 inches center to center, and the outer ones 5 inches center to center. On this line the rail-holes are 1-inch by 1½ inches oval, one fish-plate has holes ⅛-inch square and the other plate has them ⅛-inch diameter. Generally the rail-holes are 1 by 1½ inches oval, and the fish-plate holes 1-inch square. The bolts are usually ⅞-inch diameter. Angle bars are used to some extent, also fish-plates with the lower part bent to nearly embrace half the lower head of double-headed rails. For flange rails, the Z plates, with a vertical web projecting below the flange of the rail, are frequently used, as shown on the drawing of the Great Southern and Western Railway (Ireland). A space of about $\frac{3}{16}$-inch is left between the ends of rails when laying track at ordinary temperature. Lock nuts are not much used.

Cross-Ties.

The ties are usually of Baltic redwood, 10 by 5 inches by 9 feet, spaced 2 feet 9 inches to 3 feet center to center. They are almost invariably creosoted, with about 7 pounds of oil per cubic foot. Some roads have the creosoting done by contract; others have their own plant for the work. Among the latter may be mentioned the Lancashire and Yorkshire Railway and the Great Northern Railway (Ireland), both of which have very large and complete plants, and pay careful attention to the important point of tie preserving. (See Appendix B.) I will not now go further into this matter, as it has been dealt with in a paper by Mr. John Bogart, M. Am. Soc. C. E., entitled, "The Permanent Way of Railways in Great Britain and Ireland, with Especial Reference to the use of Timber Preserved and Unpreserved," and read November 20th, 1878.* I would say, however, that I do not think enough practical attention is paid in this country to the question of preserving railroad ties, and that some points in the matter may be learned from English practice.

Usually the ties are of rectangular section, but on the Midland Great Western Railway (Ireland), they are preferred of half-round section, except where the bearing plates are used. Mr. Price says that for heavy traffic he would prefer sleepers 11 by 5½ inches; he uses, however, sleep-

* Transactions, Vol. VIII, page 17, January, 1879.

ers 10 by 5 inches, 8 feet 11 inches long, always creosoted. The following is from the company's specifications: The timber is to be of good, sound Baltic red-wood, free from shakes or other defects, well seasoned and dry; 90 per cent. of both rectangular and half-round sleepers to have not less than 7½ inches diameter of heart wood; and 10 per cent. not less than 7 inches at both ends. On one side the rectangular sleepers to have 50 per cent. sharp edges down to 9 inches surface, and 50 per cent. not less than 8 inches; and on the other side all edges to be sharp. The rectangular sleepers to be grooved and bored and the half-round sleepers to be grooved, in accordance with templates, which will be supplied by the engineer. After being grooved and bored they are to be placed in a receiver and thoroughly impregnated with the best creosote oil (an equal mixture of light brown and black oil) under such pressure, and for such time, as shall entirely fill the pores with the liquid. The sleepers are not to be creosoted till they have been stacked in the contractor's premises for at least three months after inspection by the engineer. The engineer will reject, either before or after delivery, any sleepers which do not comply with the above conditions, or any sleepers the sap-wood of which has not been fully creosoted. Sections of these sleepers will be found on Plate LXVI.

Steel ties are in use on a large number of lines, and their use is being extended. They are of the "inverted trough" section, and are used mainly on divisions where there is a very heavy traffic. The bull-headed rail, with its heavy chairs, is, however, mounted on these ties, so that the entire metal track is very complicated and expensive, and represents a great amount of money sunk and absolutely wasted in metal, which with a proper form of rail would not be required at all. Each complete steel tie on the London and North Western Railway represents a considerable amount of shop work; the chairs being made of three plates rolled from the crop ends of steel rails, bent to the required shape and riveted to the tie; this work is done by the company at its own steel works at Crewe. With a well-designed flange rail of proper weight, a metal track could be obtained cheaper than the present expensive system, and fully as efficient.

The ballast consists generally of broken stone or furnace slag, on some lines covered with a boxing of gravel. On the Midland Railway the ballast has a flat outer slope and is brought up nearly level with the under side of the rail-head on the outside of the track, and level with the tops of the ties between the rails. The ballast is about 1 foot deep under the ties. Burnt clay is sometimes used.

Switches and Crossings.

With double-headed rails the switches and crossings are very substantial, the rails being supported on each tie by specially cast chairs. The ties are generally 12 by 6 inches, spaced 2 feet 4 inches and 1 foot

10 inches at joints. The points of the switch-rails are housed under the heads of the stock-rails, and the chairs upon which the points of the switch-rails slide rest on a wrought-iron plate, which is nearly as long and broad as the face of the tie. The switch-rails are connected by tie rods. With a 12-foot switch-rail the switch-rail is 12 feet long and the stock-rail 19 feet 6 inches; with a 15-foot switch they are 15 and 22 feet long respectively, and with an 18-foot switch they are 18 and 30 feet long. A drawing of a three-throw switch shows a long switch-rail of 14 feet 6 inches, a short switch-rail of 12 feet and a stock-rail of 19 feet 6 inches. The throat of the frogs is usually ¾-inch wide, and a clearance of 2½ inches is given for wheel flanges. The heel joint of the switches is usually suspended. Cast crossings, whether of steel or iron, are in less favor than they were a few years ago; the ordinary built-up crossing finds most favor and is beginning to supplant the former in India and the colonies. With flange-rail tracks the rails are supported on chairs on each tie; and some of the obtuse crossings on the Great Southern and Western Railway (Ireland), are each supported on two iron plates about 1 foot wide by 2 feet 6 inches long, placed longitudinally and bridging across two ties, to which they are spiked.

The growth of switches and crossings can be traced from the oldest line in England, the Darlington section of the present North Eastern Railway system. Until about the year 1839, the switches on this line were made of cast-iron, with a wrought-iron movable tongue pivoted at the heel with a vertical pin; the usual length of this tongue was about 3 feet. The first switches made from rails were made at the blacksmith's fire, and were 6 feet long. The stub switch has never been adopted. Until about fifteen years ago the practice in the north of England was to notch the stock-rail to receive the switch tongue (See "*A*," on Plate LXVI); long before this, however, the Southern lines had adopted Wild's patent switch, which was introduced about the year 1844. In this switch the stock-rail was left intact and the web of the rail was let in under the head of the stock-rail at the point. Stock-rails are now very rarely notched, except in the flanges of Vignoles rail switches, but the points are rarely let in as far as with the original Wild's patent (See "*B*," Plate LXVI); "*C*" represents a very common practice; "*D*" represents the practice of the North Eastern Railway, in which the switch rail is planed off straight and laid against the stock-rail, the point being topped down so that the flange of the wheel passes over it. Until recently, the London and North Western Railway used the cranked stock-rail, but it is now abandoning it; this, as will be seen by the sketch "*E*" on Plate LXVI, served the same purpose as a notch. The joint at the heel is usually suspended, and the heel chair is dispensed with, the switch-rail, as well as the rail which joins on to the heel, being buttressed by three or four special chairs, one in front of the heel and the others behind. A set of switch chairs for a 15-foot switch on the Caledonian Railway weighs

1 036 pounds; a set of seven crossing chairs for a 1 in 10 crossing, 529 pounds, and the ten check chairs for two 15-foot check rails weigh 700 pounds. Most railways prefer to rivet the splice rail of a crossing to the nose rail, instead of bolting it; the best practice is not to notch the latter, although some railways prefer this plan. On some railways it is the practice to make the crossing so that the nose rail is always on the main line, the splice rail turning into the siding; this, of course, requires the crossing to be made both right and left. (Plates LXV and LXVI). (I am indebted to Mr. Thomas Summerson, of Darlington, a manufacturer of railway plant, for much of the above information respecting switches and crossings).

The following list of the weights of some English locomotives may be interesting in connection with the subject of the track of the railroads:

	Weight in Gross Tons.	
	On driving axle.	Total.
Mersey Railway—		
(*a*). Tank engine, 6 drivers, trailing truck.....	17½	67½
Lancashire and Yorkshire Railway—		
(*b*). Express; 4-coupled, leading truck.....	14¾	41¾
Great Western Railway—		
(*c*). Express; 2 drivers, 4 leaders, single trailers...	16	49
Great Northern Railway—		
(*d*). Express; 2 drivers, leading truck, single trailers.	17	45⅕
North Eastern Railway—		
(*e*). Express, compound; 4-coupled, 1 leading axle.	18	43⅝
Midland Railway—		
(*f*). Express; 4-coupled, leading truck.....	15	42¾
London and North Western Railway—		
(*g*). Express, compound; 4 drivers, 1 leading axle.	15	42½
Caledonian Railway—		
(*h*). Express; 2 drivers, leading truck, single trailers.	17	42
Great Southern and Western Railway (Ireland)—		
(*i*). Express; 4-coupled, leading truck.....	.....	39½
North Eastern Railway—		
(*j*). Freight; compound, 6-coupled	15½	41¾

(*a*) Cylinders, 21 by 26 inches; driving wheels, 4 feet 7 inches diameter; truck wheels, 3 feet diameter; weight on leading coupled wheels, 16⅛ tons; on driving wheels, 17½ tons; on trailing coupled wheels, 17¼ tons; on trailing truck, 16¼ tons; total, 67½ tons. The tanks are at each side of the boiler, built on the frames.

(*b*) Cylinders, 17½ by 26 inches; driving wheels, 6 feet diameter; truck wheels, 3 feet 7¾ inches diameter; wheel-base of truck, 5 feet 6 inches; of driving wheels, 8 feet 7 inches; total, 21 feet ½-inch. Weight

on truck, 12⅖ tons; on drivers, 14¾ tons; on trailers, 14½ tons; total, 41¾ tons.

(*c*) Cylinders, 18 by 24 inches; driving wheels, 8 feet diameter; leading and trailing wheels, 4 feet 6 inches diameter. This is a broad (7 feet) gauge engine; similar engines for standard gauge have one pair of leading wheels, and driving wheels 7 feet diameter.

(*d*) Cylinders, 18 by 26 inches; driving wheels, 8 feet diameter; truck wheels, 3 feet 11 inches; trailing wheels, 4 feet 7½ inches; weight on truck, 8$\frac{1}{10}$ tons on front axle and 9½ tons on rear axle; on driving wheels, 17 tons; on trailing wheels, 10⅗ tons; total, 45½ tons; tender on six wheels, 4 feet 1½ inches diameter.

(*e*) Cylinders, one high pressure, 18 by 24 inches; one low pressure, 26 by 24 inches; driving wheels, 6 feet 8¼ inches diameter; leading wheels, 4 feet 7¼ inches; driving wheel-base, 7 feet 9 inches; total wheel-base, 16 feet 5 inches; weight on leading wheels, 12$\frac{9}{10}$ tons; on driving wheels, 18 tons; on trailing wheels, 12½ tons; total, 43⅖ tons. Tender on six wheels, 3 feet 9¼ inches diameter; wheel-base, 12 feet 8 inches; weight, 33 tons.

(*f*) Cylinders, 19 by 26 inches; driving wheels, 7 feet diameter; truck wheels, 3 feet 6 inches; driving wheel-base, 8 feet 6 inches; truck wheel-base, 6 feet; total wheel-base, 24 feet 6 inches; weight on truck, 14¾ tons; on driving wheels, 15 tons; on trailing wheels, 13 tons; total, 42¾ tons; weight of tender, 35 tons.

(*g*) Cylinders, two high pressure, 14 by 24 inches, driving the trailing driving wheels; one low pressure, 30 by 24 inches, driving the forward driving wheels; driving wheels, 6 feet 3 inches diameter; leading wheels, 3 feet 9 inches diameter; driving wheel-base, 9 feet 8 inches; total wheel-base, 18 feet 1 inch; weight on leading wheels, 12½ tons; on low pressure driving wheels, 15 tons; on high pressure driving wheels, 15 tons; total, 42½ tons.

(*h*) Cylinders, 18 by 26 inches; driving wheels, 7 feet diameter; truck wheels, 3 feet 6 inches; trailing wheels, 4 feet 6 inches; driving wheel-base, 8 feet; truck wheel-base, 6 feet 6 inches; total wheel-base, 21 feet 1 inch; weight on truck, 13½ tons; on driving wheels, 17 tons; on trailing wheels, 11½ tons; total, 42 tons; tender on six wheels, 4 feet diameter; wheel-base, 13 feet; weight, 33½ tons.

(*i*) Cylinders, 18 by 24 inches; driving wheels, 6 feet 6 inches diameter; truck wheels, 3 feet diameter; driving wheel-base, 8 feet 3 inches; truck wheel-base, 5 feet 3 inches; total wheel-base, 20 feet 5 inches.

(*j*) Cylinders, one high pressure, 18 by 24 inches; one low pressure, 26 by 24 inches; wheels (all coupled drivers), 5 feet 1¼ inches diameter; wheel-base, 16 feet 6 inches; weight on leaders, 14⅗ tons; on drivers, 15½ tons; on trailers, 12⅕ tons; total, 41¾ tons. Tender similar to that of engine (*e*).

While the American type of track, as a type, is probably the best that could be designed, yet there are many matters of detail in which it is open to improvement, and in some of these matters something may be learned from European practice. I now come to the description in detail of the tracks of some English railroads, but in concluding this first part of my paper I may say that I should very much like to see heavy rails on steel ties adopted for roads with heavy traffic. Of course, this is principally a question of expense, but in my opinion the metal ties should be adopted not only as a substitute for wood where, or when, timber is scarce, but as ordinary ties, for standard first-class track. In almost every large country but America, and in not a few of the smaller countries, metal sleepers have been given an extended trial, and in many cases they have passed beyond the experimental stage and are being introduced and extended very rapidly. It seems to me a pity that more is not done by American railroad engineers to try for themselves the advantages of metal track before the state of the timber supply, and the consequent excessive cost for wooden ties, compels them to take some action in the matter, for which they are not prepared.

Great Northern Railway.

The standard track of this railway consists of Bessemer steel rails, of bull-headed section, 30 feet long, weighing 82 pounds per yard. They are supported in cast-iron chairs on each tie, the chairs having a base of $6\frac{1}{2}$ inches by $15\frac{1}{2}$ inches, and weighing 40 pounds each; the joint chairs have a base of 8 by $15\frac{1}{2}$ inches, and weigh 53 pounds each. The rails have an inward tilt of 1 in 24, given by the inclination of the seat in the chair. The ties are of Baltic redwood, creosoted with not less than 35 gallons of creosote forced into a load of 50 cubic feet of timber. They are 10 by 5 inches by 8 feet 11 inches, spaced 1 foot $9\frac{1}{2}$ inches, center to center, at joints, and 2 feet $7\frac{1}{2}$ inches, center to center, intermediate. The creosoting is done by contract; the contractor provides the plant and the company finds the ground. The life of the sleepers varies, of course, but the average may be taken as about ten years. The rails are secured in the chairs by compressed fir keys driven between the web of the rail and the jaw of the chair, on the outside of the track. The ordinary chairs are attached to the ties by two trenails and one round spike; the joint chairs by two trenails and two spikes. The trenails are of English oak, and are compressed not less than $\frac{3}{10}$-inch; the keys are compressed not less than $\frac{3}{8}$-inch. The rail joints are even and are spliced with two plain, straight fish-plates, 18 inches long by $2\frac{1}{16}$ inches deep and 1-inch thick, with four $\frac{7}{8}$-inch bolts, and there is a space of $\frac{1}{4}$-inch between the plate and the web of the rail; the plates weigh 20 pounds per pair. The two outer bolts pass through the rail and fish-plates as in the ordinary joint, but the two bolts next the rail ends also pass through the jaw of the chair, which is on the out-

side of the track. The holes in the plates are 1-inch square, spaced 4½ inches, center to center. The switches and crossings are made from steel rails. (Plate LXIII).

(An estimate of the cost of laying one mile of single track road is given in Appendix "A," the prices being those of 1885).

North Eastern Railway.

The standard track of this railway consists of steel rails, of double-headed (reversible) section, 30 feet long, weighing 82 pounds per yard. They are supported in cast-iron chairs on each tie, the chairs having a base of 7¾ by 12½ inches, and weighing 40 pounds each. The rails have an inward cant of 1 in 20. The ties are 10 by 5 inches by 9 feet, and there are eleven ties to each rail, spaced as follows: 2 feet 3¼ inches, center to center at joint; 2 feet 4 inches; 2 feet 8 inches; 2 feet 10 inches; 3 feet; 3 feet ½-inch; 3 feet ½-inch; 3 feet; 2 feet 10 inches; 2 feet 8 inches; 2 feet 4 inches; and 2 feet 3¼ inches at the joint. The rails rest on wooden cushions in the seat of the chairs, and are secured by wood keys driven on the outside of the track. Each chair is attached to the tie by four 22-ounce spikes. The rail-joints are even and suspended; they are spliced by a pair of plain fish-plates and four bolts; the fish-plates weigh 13 pounds each, and a bolt and nut 24 ounces. The bolt holes in the rail are 1 by 1⅛ inch, oval. A space of ¼-inch is left between the rail ends at the joints. (Plate LX).

(An estimate of cost per mile is given in Appendix "A," the prices being those of 1887).

Lancashire and Yorkshire Railway.

The standard track of this railway consists of steel rails, of bull-headed section, 30 feet long, weighing 86 pounds per yard. The sectional dimensions are: height, 5 17/32 inches; width of head and base, 2 23/32 inches; thickness of web, 23/32-inch, sectional area, 8.52 square inches. They are supported in cast-iron chairs on each tie; the chairs having a base of 7¾ by 15½ inches, having a base area of 120 square inches, and weighing 56 pounds each. The rails have an inward cant of 1 in 20. The ties are 9 feet by 10 by 5 inches, spaced 2 feet 9½ inches and 2 feet 10½ inches, center to center, and 2 feet at joints; they are of creosoted Baltic timber and weigh 158 pounds each. Their average life is about sixteen years. The rails are secured by keys of compressed yellow pine, coated with black lead, on the outside of the track; these keys are 6½ inches long and 2¾ inches deep, tapered lengthwise from 2 to 1⅝ inches in thickness, and weighing about ½ pound each. Each chair is attached to the tie by two spikes and two trenails, the latter blackleaded. The spikes are of wrought-iron, 6¼ inches long from the underside of the head, 19/16-inch diameter, and weighing 1⅛ pounds each. The trenails are of American oak, compressed and blackleaded; they are 6 inches

long, tapering for about one-third of their length, from the head, from $1\frac{1}{2}$ inches diameter to $1\frac{1}{8}$ inches, and the remainder from $1\frac{1}{8}$ to $1\frac{1}{16}$ inches; they weigh about 4 ounces each. The joints are even and suspended; they are spliced by plain, straight fish-plates, fastened by four steel bolts, with the Ibbotson steel lock nut. The plates are of steel, 18 inches long, $3\frac{3}{8}$ inches deep on the outside and beveled to $2\frac{5}{16}$ inches on the inside; they are $\frac{7}{8}$-inch thick, and weigh 28 pounds per pair. They are so shaped as to bear only on the underside of the head and the top of the base of the rail, leaving a clear space of about $\frac{1}{8}$-inch between the plate and the web of the rail. One of each pair of plates has square punched holes to fit the square neck of the bolts, the other has round holes; the former are 1-inch square and the latter 1-inch diameter; the holes in the rails are $1\frac{1}{4}$ by $1\frac{1}{8}$ inches, oval. The inner holes are 6 inches center to center, the outer ones $4\frac{1}{8}$ inches. The bolts are $4\frac{1}{4}$ inches long from the under side of the head, $\frac{7}{8}$-inch diameter, square necked for about $\frac{5}{8}$-inch from the head, and weigh, with washers, $1\frac{3}{4}$ pounds each. A space of $\frac{1}{4}$-inch is left between the ends of the rails at joints.

Flange rails have been abandoned, except at engine pits, etc., but this flange-rail track (which is shown on the drawings) presents some interesting points. The rails are of steel, 21 feet long, weighing 72 pounds per yard. The sectional dimensions are: height, $5\frac{3}{32}$ inches; width of head, $2\frac{21}{32}$ inches; width of base, 5 inches; thickness of web, $\frac{23}{32}$-inch. They are carried on longitudinal timbers, to which they are secured by "bracket chairs," which consist practically of a pair of short angle-bars, 6 inches long, $\frac{1}{2}$-inch thick, and weighing $5\frac{1}{2}$ pounds each, bolted together through the rail with one $\frac{7}{8}$-inch wrought-iron bolt, $4\frac{1}{4}$ inches long, weighing $1\frac{1}{8}$ pounds. Each pair of plates is fastened to the sleeper by one spike and one coach-screw, passing through the horizontal flange and arranged alternately on the inside and outside of the rail. The spikes are of wrought-iron, $\frac{11}{16}$-inch diameter, $4\frac{3}{4}$ inches long under the head, weighing $10\frac{1}{4}$ ounces each; the coach-screws are $\frac{3}{4}$-inch diameter, $5\frac{1}{2}$ inches long under the head, weighing, with washers, $14\frac{3}{4}$ ounces each. The "brackets" are spaced 3 feet $1\frac{1}{2}$ inches center to center, and 2 feet 3 inches, center to center, at joints. The joints are spliced with straight wrought-iron plates, 18 inches long, $\frac{13}{16}$-inch thick, weighing 22 pounds per pair; they are bolted together by four wrought-iron bolts, $\frac{7}{8}$-inch diameter, $4\frac{1}{2}$ inches long, weighing $1\frac{1}{8}$ pounds each. The mode of attachment would seem to be unnecessarily expensive for the class of track for which it is used, but would make a very safe track for ordinary traffic.

The frogs are made of bull-headed rails, planed and spliced, with cast-iron collars or coupling chairs, each cast to the proper angle and generally embracing the wing or guard rail as well. The ballast consists of a layer of hard rough stone pitching, 9 inches deep, laid on

edge and hand-packed as closely and compactly as possible; over this is spread a layer of ashes 9 inches thick, on the top of which the sleepers are laid and packed throughout until an even surface is obtained, after which the line is boxed to the level of the underside of the rail. This company has its own plant for seating, boring and creosoting its ties, and has also a machine for attaching the chairs to the ties in the shop, thus saving work on the track. (Plate LXI).

(An estimate of cost per mile, etc., is given in Appendix "A," the prices being those of 1887. A description of the creosoting plant and process is given in Appendix "B").

Midland Railway.

The standard track of this railway consists of steel rails, of bull-headed section, 30 feet long, weighing 85 pounds per yard. They are supported in cast-iron chairs on each tie, the chairs having a base of 15½ by 7½ inches and weighing 50 pounds each; the edges of all chairs are rounded to prevent chipping. The rails have an inward tilt of 1 in 22. The ties are laid with the sawn face up and are spaced as follows: 2 feet 2 inches at joint; 2 feet 3 inches; 2 feet 9 inches; 2 feet 11 inches; 3 feet; 3 feet; 3 feet; 2 feet 11 inches; 2 feet 9 inches; 2 feet 3 inches, and 2 feet 2 inches at the joint. The rails are secured in the chairs by oak keys 7 inches long and about 2⅛ inches by 3¾ inches section. Instead of nails being used to prevent keys from dropping out, the ballast is required to be banked up level with the top of the keys. The keys are on the outside of the track. The chairs are attached to the ties by two spikes and two oak trenails. The joints are even and suspended; they are spliced by a pair of deep fish-plates, the lower part being curved to embrace the lower head, so that the bottom edges of the plates nearly meet under the rail. (Plate LXII). The plates are 18 inches long, weigh 40 pounds per pair and are fastened by four ⅞-inch steel bolts. The bolt holes in the rails are 1 inch by 1⅛ inch, oval, and the holes in the fish-plates are 1-inch square; they are spaced 4½ inches, center to center. A space of $\frac{3}{16}$-inch is left between the rail ends at ordinary temperature. The frogs are made of steel rails; for all common crossings a check rail is placed on each side, at least 12 feet in length, and much longer in special cases. The narrowest part of the throat of the frog is 1¾ inches wide. At switches the ties are 12 by 6 inches or 10 by 5 inches, of suitable length, and spaced about 2 feet 2 inches, center to center. The switch-rails are connected by 1¼-inch tie rods, and are cut down near the ends so that the tongue is housed under the head of the stock rail. The ends of wing rails at frogs are turned out with a radius of 18 inches. Wooden blocks are fitted in the "V" part of common crossings in some cases, to prevent coupling chains from catching. (Plate LXII).

Great Eastern Railway.

The standard track of this railway consists of steel rails, of bull-headed section, 30 feet long, weighing 80 and 85 pounds per yard; the 80-pound rails have a rounded head, while the 85-pound rails have vertical sides to the head. They are supported in cast-iron chairs on each tie, the chairs having a base of $6\frac{3}{4}$ by $15\frac{1}{4}$ inches, and weighing 43 pounds each. The rails have an inward tilt of 1 in 22. The ties are 9 feet by 10 inches by 5 inches; spaced from 2 feet 1 inch at the joints to 2 feet $9\frac{1}{2}$ inches at the middle. The rails are secured by oak keys, driven on the outside of the track. The chairs are attached to the ties by two $\frac{7}{8}$-inch spikes and two $\frac{1}{4}$-inch oak trenails. The joints are suspended and are spliced by deep fish-plates, similar to those of the Midland Railway; they are 18 inches long and weigh 34 pounds per pair. The bolt holes in the rails are $\frac{15}{16}$-inch by $1\frac{1}{8}$ inches, oval; the holes in the fish-plates are $\frac{15}{16}$-inch square; the bolts being $\frac{3}{4}$-inch diameter. The inner holes are spaced $5\frac{3}{8}$ inches, center to center, and the outer ones $4\frac{1}{2}$ inches. No frog is to be laid at a flatter angle than 1 in 8, and as far as possible to be limited to 1 in 6. All frogs to be laid tight to gauge, from 4 feet 8 inches to 4 feet $8\frac{1}{2}$ inches, as circumstances may require, and each line to cross on the straight, wherever possible, for at least 20 feet on each side of the crossing. All frogs to give a depth of not less than $2\frac{1}{2}$ inches clearance for the flanges of wheels. The ballast is of gravel and is 1 foot deep under the ties. (Plates LXIII and LXV).

Severn and Wye and Severn Bridge Railway.

This road was originally laid with flange rails, but double-headed rails have now been adopted on the main portions of the line, because, to quote the words of the engineer: "We found that the flange, or Vignoles, rail was troublesome and expensive to maintain and keep in order on a line where the gradients are steep, curves sharp, and on which tank engines weighing, loaded, nearly 50 tons, are employed." A peculiarity of the flange-rail track of this road is that the rails are supported in heavy cast-iron chairs having one jaw. (Plate LXIV). Two $\frac{3}{4}$-inch fang bolts pass through each chair, the nuts and washers being on the under side of the tie and the bolts being screwed up from the top. The inside bolt has a clip washer, which holds the flange of the rail, the outside flange being held by the jaw of the chair. The rail weighs 72 pounds per yard and is $4\frac{5}{8}$ inches high, with a flange $4\frac{1}{4}$ inches wide. The chairs have a base of about $5\frac{1}{2}$ inches by $10\frac{1}{2}$ inches. The main objects of the chair are, of course, to distribute the load, to prevent the rail from cutting the tie, and to keep the track from spreading at curves. These are very desirable and important points, but a well-designed shoe or sole-plate would be probably as efficient and certainly cheaper. On curves even, such a form of chair would seem to be hardly necessary, except

in special cases or under very heavy, rapid or constant traffic. The joints are spliced with fish-plates weighing 20 pounds per pair, fastened with four ¾-inch bolts. The flange rails are of steel, 21 feet long, 72 pounds per yard, carried on Baltic timber creosoted ties, 10 by 5 inches by 9 feet, spaced about 2 feet 8 inches, center to center. The double-headed rails are of steel, 29 feet long, 80 pounds per yard, carried in cast-iron chairs, which weigh 38 pounds each and are fastened to the ties by two fang bolts. The wooden keys are on the inside of the track. The ties are spaced 3 feet, center to center, but closer at joints. The ballast is chiefly furnace slag. The width at formation level (sub-grade) is 16 feet. The working load on grades of 1 in 30 is 70 tons, for freight engines with 16-inch cylinders; on grades of 1 in 40 to 1 in 50 it is about 100 tons or 120 tons. The switches on the flange-rail sections of the track have the stock rails cranked to let in the tongue of the switch-rail, the flanges of the rails being cut away to let the heads come together. The curves on these sections of track range from 462 feet and 528 feet to 2 970 feet, with a great number of about 600 and 800 feet. On the sections laid with double-headed rails the curves range from 660 feet to 1 980 feet.

On the Severn Bridge, which is owned by this company, the track consists of bridge rails (Plate LXIV), 24 feet long, weighing 68 pounds per yard, laid on longitudinal sleepers. The rails are secured to the sleepers by four fang bolts at the joints, two fang bolts at the middle and coach-screws at intermediate points. Sole-plates are used at the rail joints. There is an angle iron guard rail, 4½ by 4½ inches, fastened to the sleepers by fang bolts and tied to the track rail by iron sole-plates. The longitudinal timbers are of creosoted yellow pine, 14 by 7 inches, connected by transoms and tie rods at intervals of 11 feet. (This track is very similar to Brunel's original type of track for the Great Western Railway, which is still in use on the 7-foot gauge portions of that line.)

Great Northern Railway (Ireland).

On this line (Irish gauge—5 feet 3 inches), both bull-headed and flange rails are used, the former being considered the best for sections with heavy grades and sharp curves. The bull-headed steel rails weigh 75 pounds per yard and are supported in cast-iron chairs weighing 36½ pounds each, being secured by wooden keys, which are driven on the inside of the track. The chairs are fastened to the ties by three spikes, ¾-inch diameter. The joints are spliced with deep bent fish-plates, somewhat similar to those of the Midland Railway, except that the bottom ends of the plates do not nearly meet under the rail, a space of 1½ inches intervening. The plates are of steel, 18 inches long and are fastened by four bolts. The rail-head has a top table of 10 inches radius, semicircular top corners of ½-inch radius, a vertical portion $\frac{7}{16}$-inch deep, and bottom corners of ⅜-inch radius. The flange rails are of steel,

21 feet long, and weigh 79 pounds per yard; they are $4\frac{3}{4}$-inches high, with a base of 5 inches, and a head of similar shape to that of the bull-headed rails. At the joint ties the rails are secured by one $\frac{3}{4}$-inch fang-bolt and one jagged spike, the former passing through the flange of the rail; at the middle tie each rail is fastened by two fang-bolts, which grip the flange by means of clips or washers; these washers have a sharp projecting rib at one end, which cuts into the wood of the tie when the bolt is screwed up. The bolts have square heads $\frac{7}{8}$-inch deep, $1\frac{1}{8}$ inches square at the top and $1\frac{3}{16}$ inches at the bottom. At intermediate ties each rail is fastened by two jagged spikes. The joints are spliced with one straight plate and one Z-plate (Plate LXIII), the latter being on the outside of the track. The plates are of steel, 18 inches long, and the nuts of the fish-bolts are on the inside of the track. Both forms of rail are laid with an inward inclination of 1 in 20; this being secured in the chair seat for the bull-headed rails and by adzing out a seat in the tie for the flange rails. When relaying, $\frac{3}{8}$-inch is allowed for expansion at rail joints. The switches are made out of steel rails, planed down to form the switch rail, which slides on cast-iron chairs firmly bolted to the stock rail. Cast-steel reversible block crossings (frogs) are used. The joints are even and suspended. The ties are rectangular, 10 by 5 inches, and 8 feet 11 inches long; they are spaced 2 feet 4 inches at joints, 2 feet 10 inches next to the joints, and 3 feet intermediate. They are of creosoted Baltic timber, and cost, when sawn, grooved and creosoted, 88 cents each. This company pays particular attention to its ties, and has a complete plant for sawing, cutting the rail seats, and creosoting. (Plates LXIII and LXIV).

(For particulars of the creosoting plant and process, see Appendix "B").

West Riding and Grimsby Railway.

The original track of this line was a good example of a heavy flange-rail track. (Plate LXIV). It consisted of flange rails 24 feet long, weighing 83 pounds per yard, carried on ties 10 by 5 inches, by 8 feet 6 inches, spaced 1 foot 10 inches at joints and 2 feet $9\frac{1}{4}$ inches intermediate. The inward inclination of 1 in 20 was given to the rails by cutting an inclined seat in the tie, which seems to be an objectionable feature, tending to cause the flange of the rail to cut into the tie, though this may have been neutralized to some extent by the wide base of the rail, 6 inches. The joints were suspended and were spliced by straight fish-plates 15 inches long, weighing 24 pounds per pair, with four $\frac{7}{8}$-inch bolts, the nuts of which were on the inside of the track; the bolts were spaced 4 inches, center to center, and weighed 5.2 pounds per set of four. Each rail was fastened to the joint ties by two $\frac{3}{4}$-inch fang-bolts, passing through a $\frac{1}{8}$-inch hole in the flange, the fang nut being at the under side of the tie and the head of the bolt bearing on a washer on the rail

flange. The intermediate fastenings consisted, I believe, of spikes and fang-bolts, all passing through the flange, a practice which is costly and objectionable in other ways. The road, however, was acquired by the Great Northern Railway and the track was taken up and the line relaid with the Great Northern standard track, previously described, entailing what would seem to have been an enormous and unnecessary expense, the new track costing about $8 000 per mile, with rails at $25 per ton. A comparative estimate of the cost of construction for this flange-rail track and the old track of the London and North Western Railway, with an 84-pound double-headed rail in chairs, shows $8 641 per mile for the former, and $10 476 for the latter, a difference of $1 835 per mile in favor of the flange rail; these prices are from old estimates and are not reliable for the cost of modern track, but as they are both for about the same date they will suffice for comparison.

Great Western Railway.

On this line there are used bridge rails, bull-headed rails and flange rails. The former are on the 7-foot gauge portions of the line, and are secured by screws and fang-bolts to longitudinal timbers. This gauge, rail and form of track was designed by Mr. Brunel, and the riding over this track at express speed is wonderfully easy and steady. The rails are quite light, 68 pounds per yard, 6½ inches base, 3 inches high. The timbers are of creosoted pine, 15 inches wide, 7½ inches deep on the outer side and 7 inches on the inner side, thus giving the rails an inward inclination. At intervals of 11 feet there are transverse timbers, about 6 inches square, notched into the longitudinals and fastened to them by iron angle-braces or knees. The clear distance between the inner rails on double track is 6 feet 4 inches, and the inner longitudinals of each track are connected at intervals of about 14 feet by cross-pieces about 6 inches square. A strip of tarred felt is laid under the whole length of the rails. The broad-gauge portions have now a third rail for standard gauge, and new lines are laid to standard gauge with bull-headed rails weighing 86 pounds per yard, carried in cast-iron chairs weighing 46 pounds each. Double-headed rails are not used, as they cause the trains to ride roughly if reversed, in consequence of the indentations made by the chairs. The joints are even and suspended. Flange rails and chairs are secured to the ties by fang-bolts $\frac{13}{16}$-inch in diameter; each chair has two fang-bolts. The wooden keys are placed on the outside of the track. The fish-plates for the bull-headed rails are 20 inches long and 3½ inches deep, with holes 5 inches center to center. The holes are of peculiar shape, being about three-fourths of a circle and then tapering off in a triangular form, making a somewhat kite-shaped hole with the narrow part pointing outward to the end of the plate. This narrow part receives a projection on the neck of the $\frac{13}{16}$-inch bolt, in order to prevent turning; the rail-holes are circular. The fang-nuts are 3½ inches

square. A space of $\frac{1}{8}$-inch is left between rail ends at joints. The ties are of creosoted pine, 9 feet long, 10 inches by 5 inches; they cost 78 cents each, including creosoting. They are spaced about 2 feet 8$\frac{1}{4}$ inches. The ballast used is gravel, cinders, stone, slag, etc. The maximum grade on the system is 1 in 30, and the curves range from 330 feet to two miles radius. The bull-headed rail is now the standard for this line. (Plate LXIII).

Great Southern and Western Railway (Ireland).

On this line, flange rails, weighing 74 pounds per yard, are used, but the bull-headed rail is considered the best where traffic is heavy. The joints are even and suspended, spliced with angular (Z) fish-plates, 18 inches long, weighing 14.74 pounds each, and having four square holes. The fish bolts have square necks, and weigh 17$\frac{1}{2}$ ounces each. Plain straight fish-plates are also used. The rail holes are 1 inch by 1$\frac{1}{2}$ inches, oval; the middle ones are spaced 6 inches and the outer ones 4 inches, center to center. The rails are 30 feet long, and are carried on eleven ties of Baltic redwood, 9 feet long by 10 inches by 5 inches, creosoted with an average of 3.39 gallons of oil each. The life of the ties averages fifteen to twenty years. The ballast is of gravel, 2 feet deep from the top of the rail, and covers the ties. The gauge is 5 feet 3 inches; 6 feet between tracks; width at sub-grade 28 feet in cutting and 32 feet in bank. The sharpest curve is 1,000 feet radius, and the steepest grade 1 in 60. (Plate LXIV).

Midland Great Western Railway (Ireland).

This line is laid with flange rails weighing 79 pounds per yard, the specifications and tests for which have been already given. The joints are spliced with L fish-plates, weighing 14 pounds, having a narrow horizontal flange at the bottom. The ties are preferred spaced 3 feet 6 inches, center to center, this being considered better than 3 feet; at joints they are spaced 2 feet. The rail is of unsightly appearance, and has an unnecessary amount of metal at the base of the web. The joints are even and suspended. At the joint and middle ties the rails rest on sole-plates 8$\frac{1}{2}$ inches by 6 inches; the channel part for the rail is 5$\frac{1}{16}$ inches wide, this part is $\frac{3}{8}$-inch thick, while the sides are $\frac{1}{2}$-inch thick; in each side is a 1$\frac{3}{8}$-inch hole for the fang-bolt. The head of the bolt has a washer which grips the rail flange, and the nuts of the two bolts in each tie are held in a single "channel washer," on the underside of the tie. (Plate LXIII). This washer is 10$\frac{1}{2}$ inches long, 3 inches wide, channel 2$\frac{1}{8}$ inches wide; it is $\frac{1}{4}$-inch thick, with flanges $\frac{1}{4}$-inch deep; the holes are 1$\frac{1}{4}$-inch by 1$\frac{1}{2}$-inch. The ballast consists of mixed gravel and coal ash for bogs. The steepest grade is 1 in 65; maximum grade for new lines, 1 in 100. The sharpest curve on the line is $\frac{1}{4}$-mile radius; the sharpest

in yards is $\frac{1}{5}$-mile. The heaviest tank engine is 44 tons, with 15 tons on driving wheels; the heaviest ordinary engine is 57½ tons, with tender weighing 13 tons. The switches and frogs are made of steel rails, and the quantities of material are as follows:

SWITCH.

No. 2. Rails, 26 feet 6 inches long.
" 2. " 13 " 3 " "
"12. Wrought-iron slide chairs.
" 2. Cast-iron heel blocks.
" 2. Connecting rods.
" 1. Pulling rod and pins (turned).
"12. Slide chair, $\frac{7}{8}$-inch bolts and nuts.
" 8. $\frac{7}{8}$-inch heel bolts.
"24. $\frac{3}{4}$ " fang-bolts.
"36. $\frac{5}{8}$ " rivets.
" 2. Fish-plates.
(All to receive one coat of red lead.)

FROG.

No. 2. Point rails, 9 feet 9 inches long.
" 1. Wing rail, 16 feet long.
" 1. Wing rail, 11 feet 6 inches long.
" 5. Crossing plates.
" 9. Cast-iron chogs.
" 8. Crossing body bolts, $\frac{7}{8}$i nch.
" 10. Wrought-iron clips (planed and drilled).
" 10. Fang-bolts, 9 by $1\frac{1}{16}$ inches.
" 34. $\frac{3}{4}$-inch rivets.
(All to receive one coat of red lead.)

ISLE OF WIGHT RAILWAY.

On this line double-headed steel rails are used, weighing 75 and 78 pounds per yard, the latter being now adopted as standard; the head is $2\frac{3}{8}$ inches wide and the web $\frac{3}{8}$-inch thick. Although reversible, the rails are not turned over, experience showing that they are rough to travel over and more liable to break. With the light traffic on this line the 78-pound rails will last from fifteen to twenty years, according to their position in the track. The rails are 24 feet long. The chairs are of cast-iron, weighing 35¼ pounds each, and are fastened to the ties by two hollow trenails, an iron spike being driven into the trenail when the latter is in place. The joints are suspended and are spliced by straight steel fish-plates, 18 inches long, 3 inches deep, $\frac{3}{4}$-inch thick in the web, and thicker at top and bottom; they weigh about 23 pounds per pair; the fish-bolts are $\frac{3}{4}$-inch in diameter and weigh 1.28 pounds each.

normal temperature (60 degrees) a space of ⅜-inch is left for expansion at the joints. The old 70-pound flange rails were fastened to the ties by ⅝-inch fang-bolts, one inside and one outside, alternately, with large triangular fang nuts under the tie. The ties are of Baltic timber, 9 feet by 10 by 5 inches, spaced 2 feet 4 inches at joints and 2 feet 8½ inches intermediate, nine ties to a rail. They are creosoted with 7 pounds of fluid per cubic foot of timber and cost 84 cents each. Their average life is fifteen years in the main line and a few years more in side tracks. The ballast is of chalk and gravel, obtained on the island, laid 12 to 18 inches deep and 12 feet wide. The switches and crossings are made of steel rails; the switch rails are 12 feet long, well cut away at the points so as to be housed under the head of the stock rail for about 6 inches. The steepest grade is 1 in 70 for about two miles; there are numerous curves, a few of 792 feet radius. The traffic is principally passenger, and there are twelve to fourteen passenger trains each way per day and one freight train each way. Tank engines are used, with side tanks; the passenger engines weigh 25 tons, freight engines 28 tons; the driving and trailing wheels are 5 feet diameter (coupled), and the leading wheels 3 feet 6 inches diameter; the weight on the driving wheels is 12 to 13 tons. Mr. Conner, the former engineer, says he considers the road described "a good reliable track for the traffic, and over twenty years of experience has shown the superiority of double-headed rails with chairs, over flange or Vignoles rails, it being a firmer and stronger road, cheaper to maintain and easier to repair."

Great North of Scotland Railway—Speyside Division.

The Speyside Railway is a single line, which was constructed in 1863. The track consists of iron rails, 21 feet long, weighing 65 pounds per yard, supported in cast-iron chairs weighing 20 pounds each, and joint chairs weighing 25 pounds each. The rails are secured in the chairs by keys, which are placed on the outside of the track; the keys in the ordinary chairs are of wood, those in the joint chairs are iron cotters. The joints are insistent, the rail ends resting in a joint chair; fish-plates are used. Each chair is fastened to the tie by two spikes. The ties are of Scotch fir, placed 3 feet apart. The ballast consists of broken stone and gravel.

The main line of the Great North of Scotland Railway is laid with double-headed steel rails, weighing 72 and 80 pounds per yard, but I mention this division as a specimen of a light track with double-headed rails. The description of the track is taken from a recent report by Major-General Hutchinson, of the Board of Trade, upon a slight accident which occurred to a mixed train. The accident was a derailment of the engine, caused by the breaking of a spring on the tender; the accident is attributed to a defective spring, but the report states that "very

probably the fracture of this spring would not have caused an accident if the engine had been running upon a better and stronger road." The road was not in good condition at the time. It is to be presumed that the track on this division will sooner or later be replaced with the standard track, but with a 75-pound steel flange rail, secured by bolts to the ties, and with a well-constructed track, the line would probably be of ample s rength for the traffic, costing less for material and no more for maintenance. At the time when a 65-pound rail was sufficient, the cast-iron for chairs was so much unnecessary metal in which money was sunk for no useful purpose and giving no return in efficiency.

The illustrations accompanying this paper are:

Plate LX. Permanent Way, North Eastern Railway.
" LXI. Permanent Way, Lancashire and Yorkshire Railway.
" LXII. Permanent Way, Midland Railway.
" LXIII. Nine-rail Sections; Rail Joint of Great Northern Railway; Rail Joint of Midland Great Western Railway of Ireland; Crossing of Great Eastern Railway.
" LXIV. Permanent Way of Great Northern Railway of Ireland; of Severn and Wye and Severn Bridge Railway; of Great Southern and Western Railway of Ireland; of West Riding and Grimsby Railway.
" LXV. Switch of Great Eastern Railway.
" LXVI. Sections of Switch Rails. Sections of Timber Cross Ties of Midland Great Western Railway of Ireland.

APPENDIX "A."

[Estimates of Cost.]

1.—GREAT NORTHERN RAILWAY—ESTIMATE OF COST OF ONE MILE OF SINGLE TRACK. PRICES OF 1885.

Rails	129 tons	at	$25 00	$3 225 00
Chairs	77 "	"	17 50	1 347 50
Plates	3.3 "	"	37 50	123 75
Bolts	$\frac{938}{1000}$ "	"	60 00	56 28
Spikes	3.77 "	"	45 00	169 65
Ties	No. 2 112	"	87½	1 848 00
Keys	" 4 224	"	22 50	95 04
Trenails	" 4 224	"	17 50	73 92
Labor	1 760	"	25	440 00
				$7 379 14
Contingencies, 10 per cent				737 91
				$8 117 05

NOTE.—This does not include ballast; single line = 4 777 cubic yards at 63½ cents $3 033 39

2.—NORTH EASTERN RAILWAY—ESTIMATE OF COST OF ONE MILE OF SINGLE TRACK. PRICES OF 1887.

Rails	129 tons	at	$22 50	$2 902 50
Chairs	69 "	"	12 50	862 50
Spikes*	No. 11 616	"	18 75	217 80
Fish-bolts and nuts	" 1 408	"	26 25	36 96
Fish-plates	" 704	"	15	105 60
Wood keys and cushions	" 7 744	"	12 50	58 08
Ties, creosoted	" 1 936	"	70	1 355 20
Labor of laying	1 760 yards	"	12½	220 00
Ballast,† 13 feet wide 18 inches deep	3 588 cubic yds.	"	11	394 68
Total				$6 153 32

* Say 3 in each chair; but only two are often used.

† Coke ballast is obtained from the collieries in the immediate vicinity of the line, and is supplied and loaded up free by the colliery owners, as they are glad to get rid of it; 11 cents per cubic yard is an average charge intended to cover carriage, tipping and spreading.

3.—Lancashire and Yorkshire Railway—Estimate of Cost of One Mile of Single Track. Prices of 1887.

Rails	3 520 yards	135.1 tons,	at	$22 50	$3 039 75
Chairs	3 872 No	96.8 "	"	15 00	1 452 00
Fish-plates	352 "	2.2 "	"	27 50	60 50
Fish-bolts	704 "	.6 "	"	80 00	48 00
Spikes	7 754 "	3.9 "	"	32 50	126 75
Ties	1 936 "		"	75	1 452 00
Trenails	1 744 "		"	17 50	135 52
Keys	3 872 "		"	19 50	75 50
Laying 1 760 yards			"	25	440 00
Total					$6 830 02

A later estimate, the prices of which are a little lower than the foregoing, gives the following details of prices per rail length, or 10 linear yards:

Material.

11 Ties		$5 92
22 Chairs		7 79
44 Spikes		32
44 Trenails		21
20 yards of rails		16 08
22 Keys		44
4 Fish-plates		63
8 Bolts		40
5 cubic yards top ballast for boxing up		90
		$32 69

Labor.

10 linear yards laying	$1 70	
2 tons carriage	96	
4 hours trucking and unloading	52	
		$3 18
		$35 87

Or $3.58 per linear yard.

The weight of the track in pounds is as follows:

		For 10 yards.	For 1 yard.
Steel.	Rails, 1 760, Plates, 56, Bolts, 12,	1 828	182.80
Wrought-iron		49½	4.95
Cast-iron		1 232	123.20
Wood.	Ties, 1 738 Trenails, 11 Keys, 11	1 760	176.00
		4 869½	486.95

APPENDIX "B."

[Treatment of Railway Ties.]

(1.)—Lancashire and Yorkshire Railway.

The ties, after being well seasoned, are passed through a combined adzing and boring machine, which first cuts out a seat, about $\frac{1}{16}$-inch deep, for the chairs, in order to give them a uniform bearing, and then simultaneously bores the eight holes required for chair fastenings in each tie. The machine will seat and bore about 100 ties per hour.

The ties are then placed on small iron trucks and drawn on a tramway of 3-foot gauge into the cylinder, which contains eight trucks with 47 ties each, or 376 ties in all. The cylinder is 77 feet long, 6 feet internal diameter, built of $\frac{1}{2}$-inch wrought-iron plates and having egg-shaped ends. When the full number of ties has been put in, the doors or covers are put on and hermetically fastened by means of dog-bolts and screws, and the air exhausted by a steam ejector. The creosote is then introduced, heated to a temperature of from 100 to 120 degrees Fahr.; the air pump then ceases to work and the pressure pump is put into operation, the full pressure of 150 pounds per square inch being obtained in about ten minutes; this pressure is maintained for about fifty minutes, and is then withdrawn. The spare creosote is allowed to run back into the reservoir under the cylinder, the cover is removed, and after the ties have been left to drip for about fifty minutes, they are taken out of the cylinder. About three gallons of creosote are allowed for each tie, or 9½ pounds per cubic foot of timber. The efficiency of the process is ascertained by weighing three or four ties out of every charge, both before and after the operation, the additional weight showing the quantity absorbed, which averages about 30 pounds per tie.

Average weight of tie before creosoting.....	128	pounds.
Gain in weight during process.....	30	"
Average weight of creosoted tie.....	158	"

The whole operation for one charge of ties occupies about one hundred and thirty-two minutes, as follows, but varies slightly, however, according to the moisture in the timber:

Ejection vacuum.....	13	minutes.
Pumping commenced and tank filled.....	9	"
Full pressure obtained in.....	10	"
" maintained for.....	50	"
Spare creosote allowed to drip from ties.....	50	"
Total.....	132	"

From the creosoting cylinder the timbers are run back into the chairing shed, where the chairs are attached to the ties by a machine (somewhat on the style of a steam hammer) which, at one stroke, drives the four fastenings for each chair. This machine will "chair" about 70 ties per hour.

The time occupied in seating, boring, creosoting and chairing 376 ties is as follows:

	Hours.	Minutes.
Seating and boring	3	40
Running trucks into cylinder	..	20
Creosoting	2	12
Withdrawing charge from cylinder	..	20
Chairing	5	14
Total	11	46

or 1 minute and 53 seconds per tie.

The cost of the operations, not including the value of the machines, is as follows:

Loading white ties, per 100	$ 36
Adzing and boring, "	62
Tanking "	64
Creosote, 300 gallons at	6.75
Chairing and spiking, per 100	2.44
	$10 81

or 10.81 cents per tie.

The whole of the work is done at the company's store yards at Castleton and Knottingley, and is let piece work at the above rates.

(2.)—Great Northern Railway (Ireland).

In 1876, when a number of railways were amalgamated to form this system, the new company decided that all the ties should be creosoted, and that to insure the work being efficiently performed, it would erect suitable plant of its own for sawing, grooving and creosoting the timber to be used for ties. After being sawed, the ties are taken to the grooving machine, which forms a groove or seat for the base of flange rails by means of cutters making 2 000 revolutions per minute. Boring machinery, with twisted augers, was used for a short time, but the adoption of the improved ragged spike, which cuts its own way without splitting the tie, enables holes to be entirely dispensed with, and insures a tighter fit of the spike. After being grooved the ties are run out into the yard on a tramway of 30-inch gauge, and stacked to a height of 14 feet, alternate tiers on edge and on flat.

The cylinder is 60 feet long (6 tie lengths), 6 feet diameter, built of ⅜-inch plates. The safety valve is set at 110 pounds, but seldom rises; it is, however, sometimes lifted to release air and water when the pressure pumps are working. There are six tanks, of such a size that a vertical inch of the six tanks represents 156 gallons; a float is connected with a gauge and scales, which show the gallons or pounds of creosote forced into the cylinder. There are 1¼-inch pipes in the cylinder, through which steam is forced to heat the creosote to 120 degrees Fahr., thus dissolving the naphthaline, etc., and rendering the creosote quite fluid. There is an air pump, 6½ by 10 inches, which exhausts the air from the cylinder, and the creosote enters by the atmospheric pressure on the tanks; the partial vacuum does not extract the sap or affect the timber. When the cylinder is nearly full, the valve is closed, air pump stopped, and the two force pumps, 3 by 4 inches, put at work. Three hours of steady pressure are required. The consumption of oil varies from 140 to 180 casks, of 36 to 38 gallons each, per week; and the quantity used annually is about 250 000 gallons. The average quantity of creosote injected is 2.35 to 2.57 gallons, or 25 to 27 pounds per tie. About nine months seasoning is customary, but a longer period is considered desirable so as to insure dryness.

"Little or no creosote can be forced into a thoroughly wet sleeper, even at high pressures, and a thoroughly dry sleeper will readily absorb a large quantity of oil, which, when solidified by exposure to the air, no moisture, either from air or wet ground, will succeed in removing."

[The information given above is briefly abstracted from a highly interesting paper: "Description of a Creosoting Yard for Railway Purposes," by Mr. W. Greenhill, M. I. C. E. I., an engineer of this railway, read before the Institution of Civil Engineers of Ireland, in May, 1886. The paper contains very full particulars, in detail, of the plant and process, results of tests, cost, etc., and is especially interesting in that it describes work done by a railway company in treating timber for its own use.]

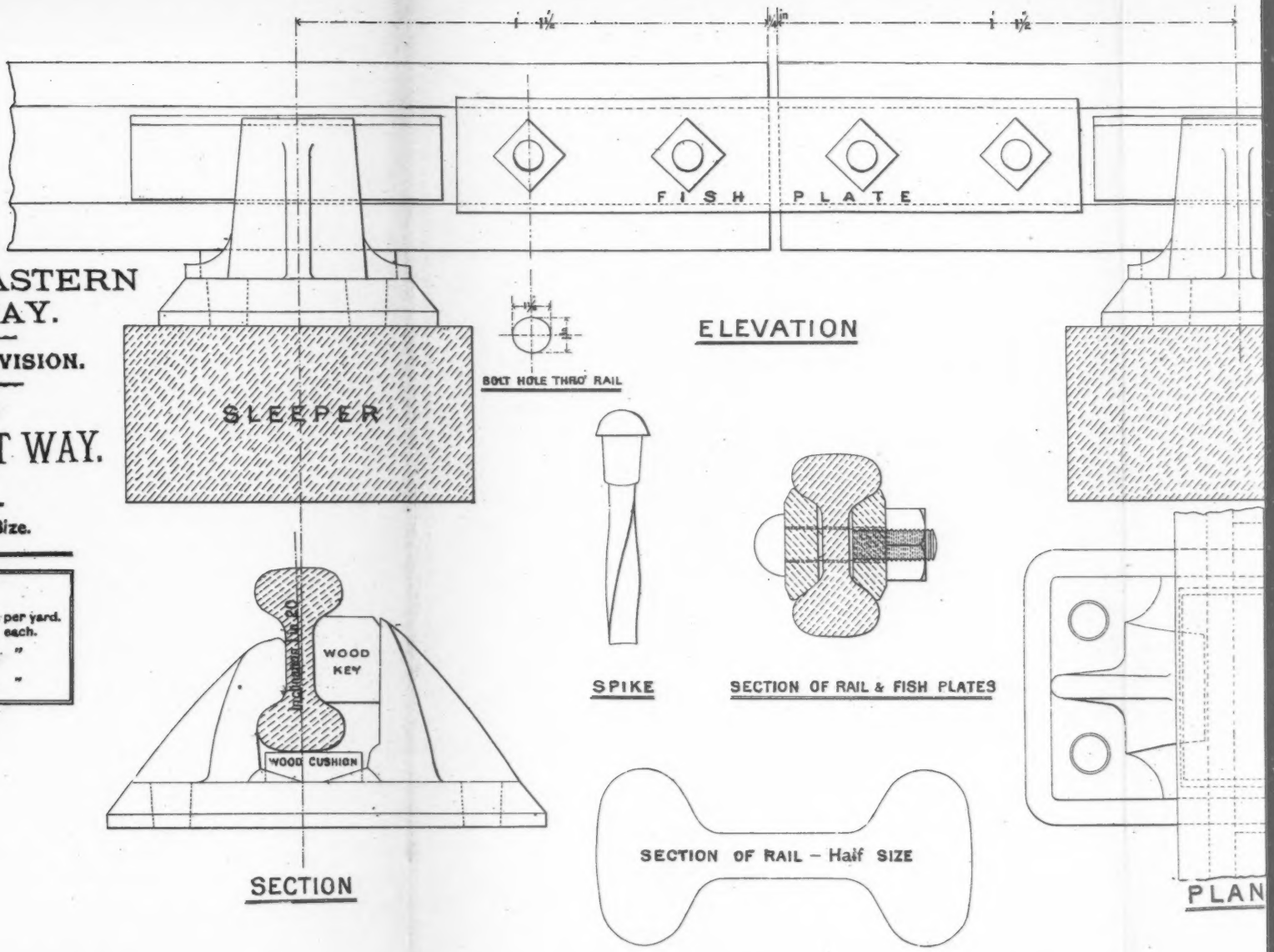
NORTH EASTERN RAILWAY.

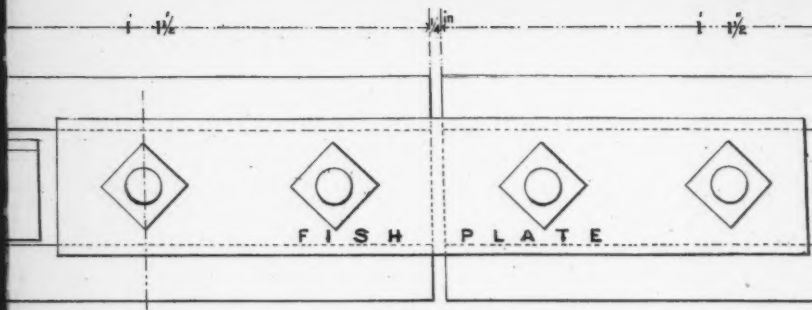
SOUTHERN DIVISION.

PERMANENT WAY.

Scale Quarter Size.

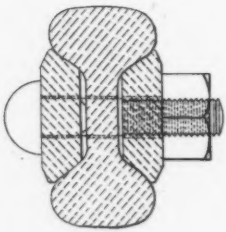
WEIGHTS.		
Rail	... ...	82 lbs. per yard.
Chair	... ...	40 „ each.
Fish Plate	... ...	13 „ „
Bolt and Nut	...	24 oz.
Spike	... ...	22 „ „





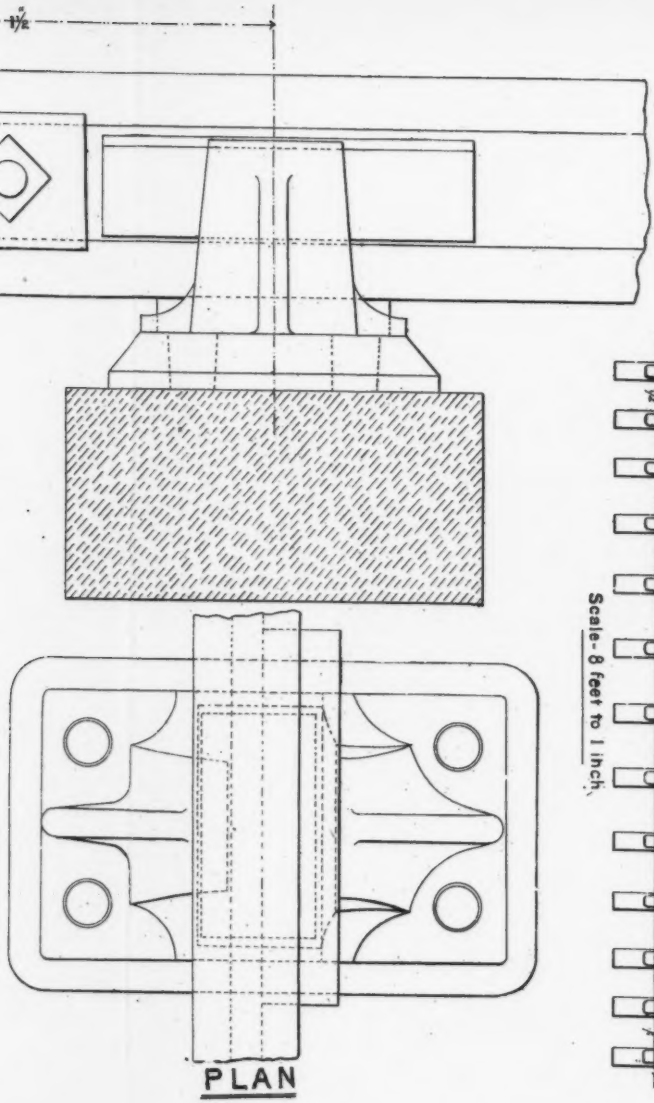
ELEVATION

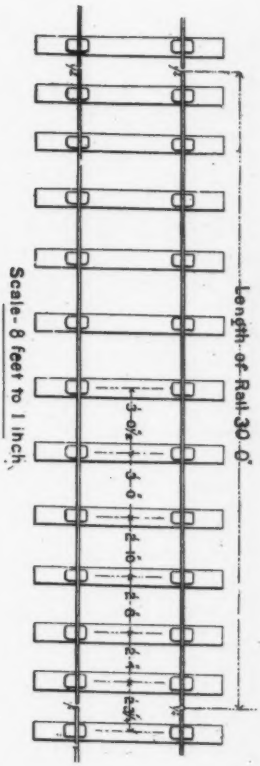
SPIKE



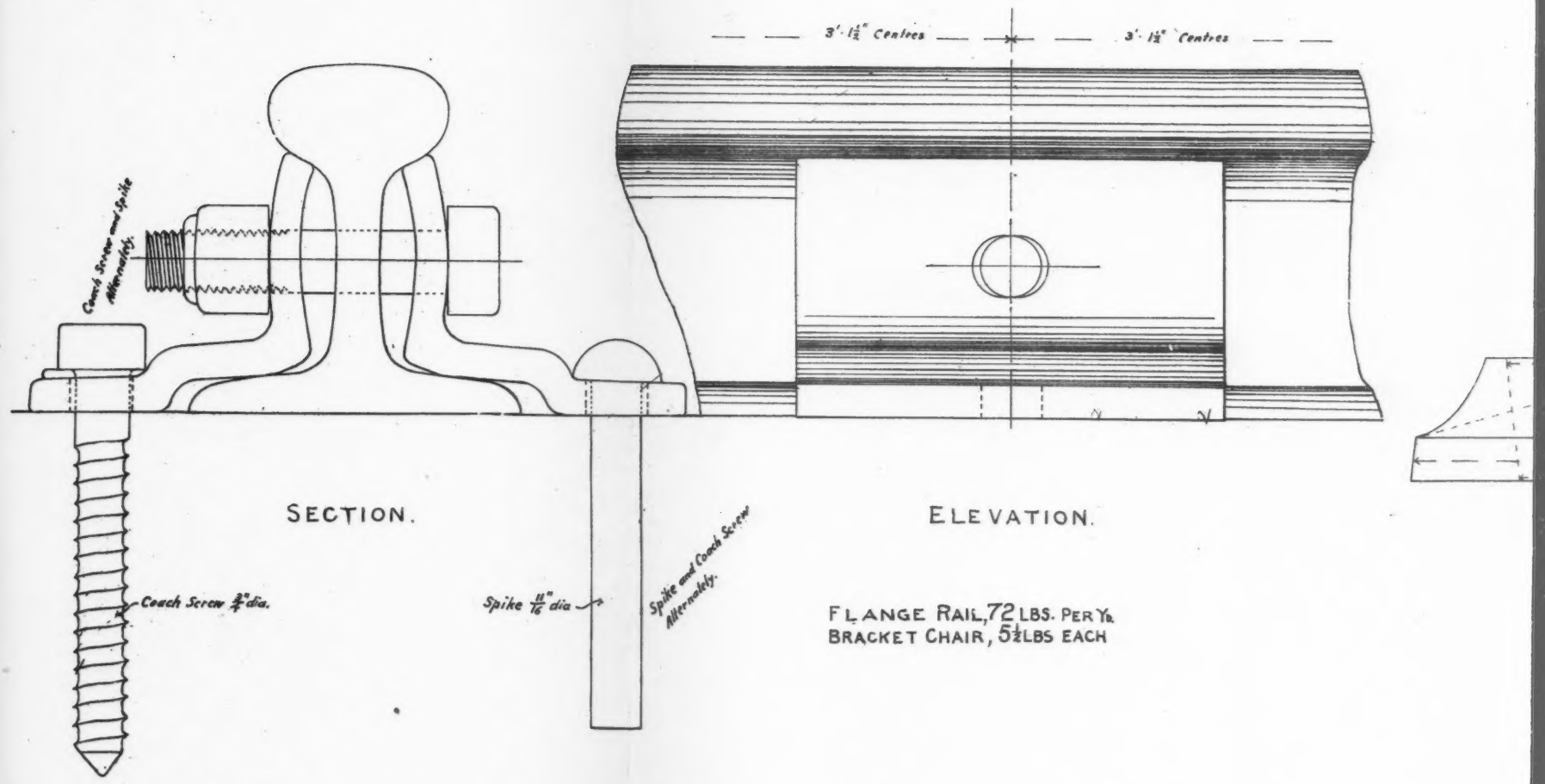
SECTION OF RAIL & FISH PLATES

PLATE LX
TRANS. AM. SOC. CIV. ENGNS.
VOL. XVIII Nº 388.
TRATMAN ON ENGLISH
RAILROAD TRACK.





LANCASHIRE & YOR



SECTION.

ELEVATION.

FLANGE RAIL, 72 LBS. PER YD.
BRACKET CHAIR, 5½ LBS EACH

FLANGE RAIL TRACK.

LANCASHIRE & YORKSHIRE RY.

PLATE LXI.
TRANS. AM. SOC. CIV. ENGNS.
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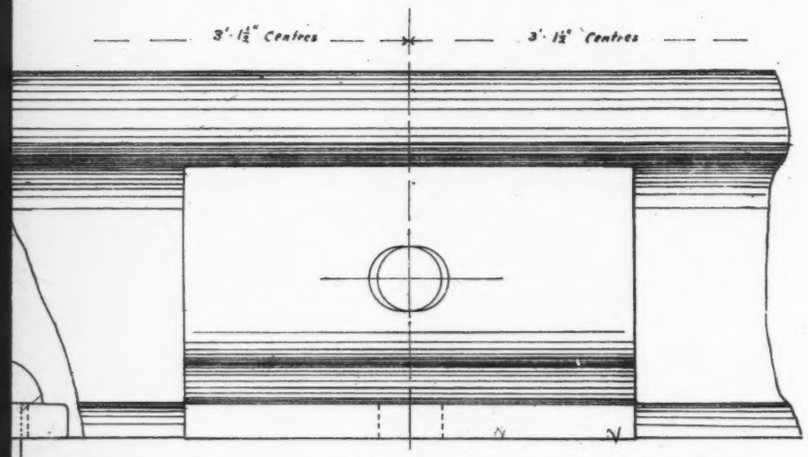
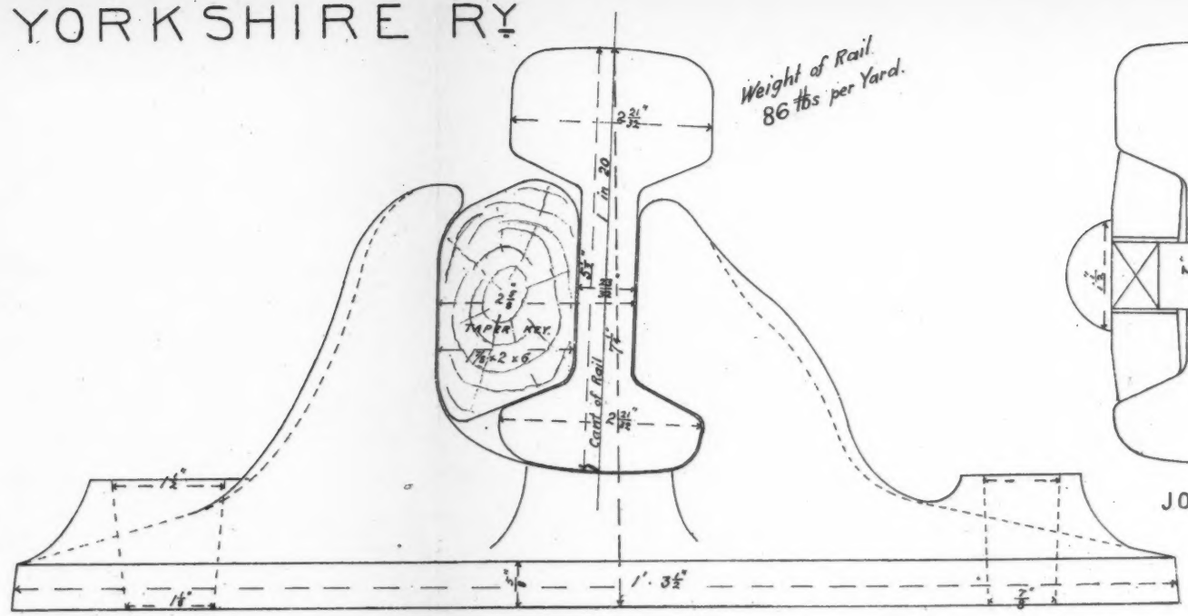
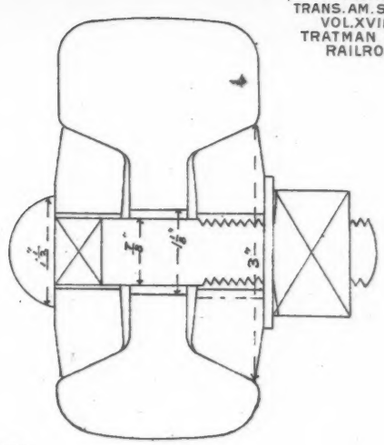
TRATMAN ON ENGLISH
RAILROAD TRACK.



ELEVATION.



CHAIR AND BULL-HEADED RAIL.

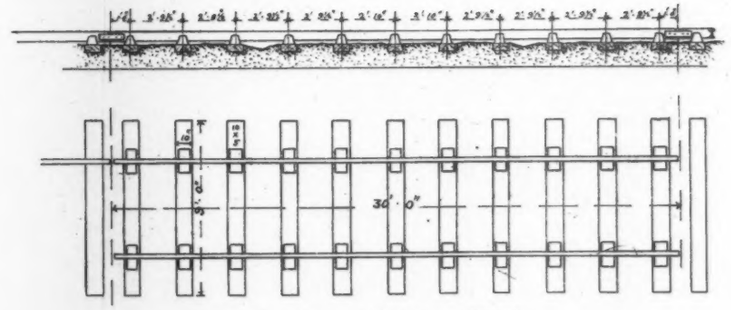


JOINT.

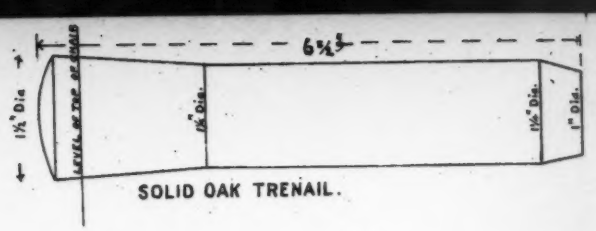
Spike and Coach Screw Alternately.

FLANGE RAIL, 72 LBS. PER YD.
BRACKET CHAIR, 51 LBS EACH

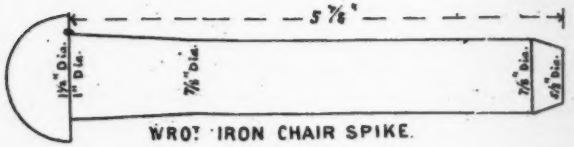
E RAIL TRACK.



PLAN AND ELEVATION OF TRACK.

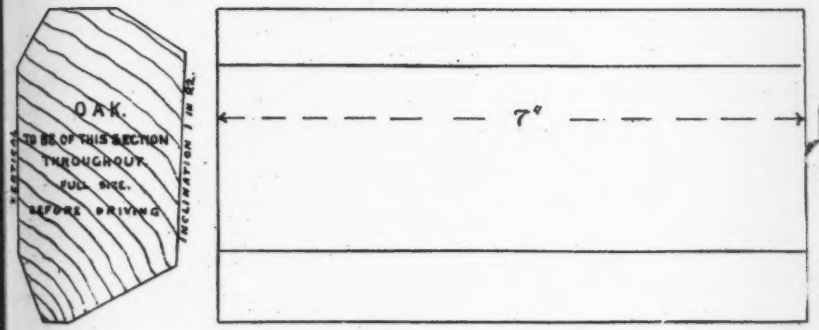


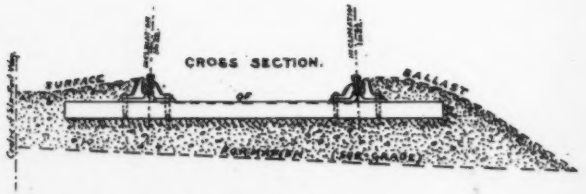
SOLID OAK TRENAIL.



WROT IRON CHAIR SPIKE.

WOOD KEY FOR 85 LBS. RAIL.



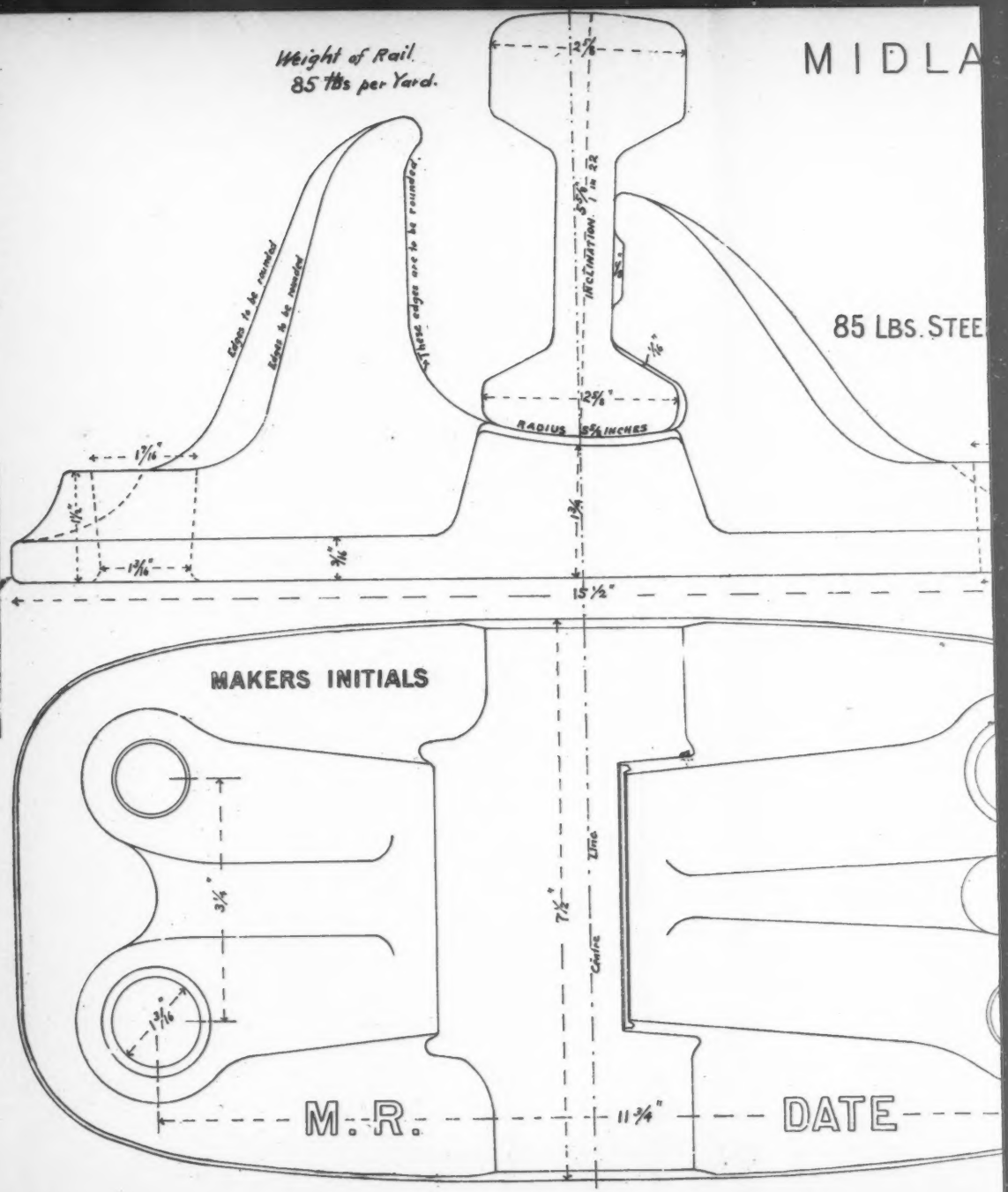


NOTE. *The Trenails and Spike holes must be bored quite through the Sleeper.*
Spikes and Fish bolts are to be dipped in Tar before using.
Trenail heads only to be coated with Tar after driving.
The Keys should be driven in the same direction as the train travels, wherever practicable.
Nuts to Fish bolts to be on outside of rails.
Ballast to be level with top of Sleepers in the four foot-way, and level with top of Keys at sides.
Gripe to be cut and Drains put in where necessary, so that no water is allowed to remain,
on the Line or under the Ballast.
The Rails are to be laid with the LETTERS on the outside.
The Sleepers are to be laid with the sawn Face upwards.

Weight of Rail
85 lbs per Yard.

MIDLA

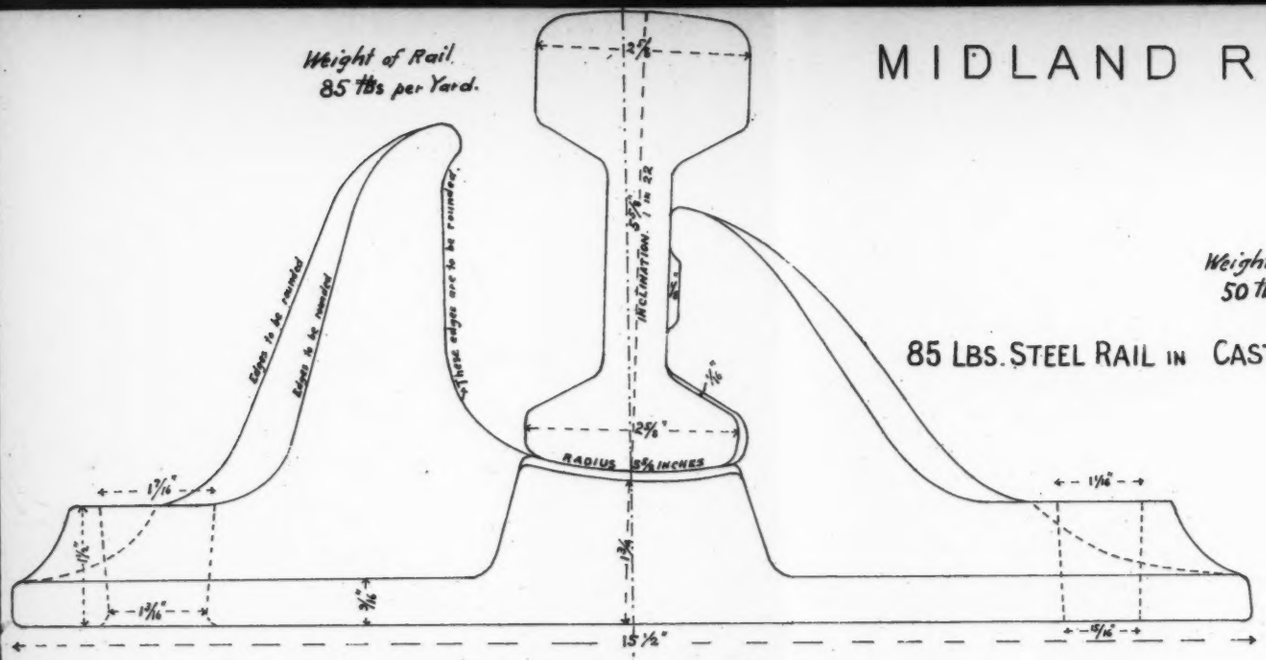
85 LBS. STEE

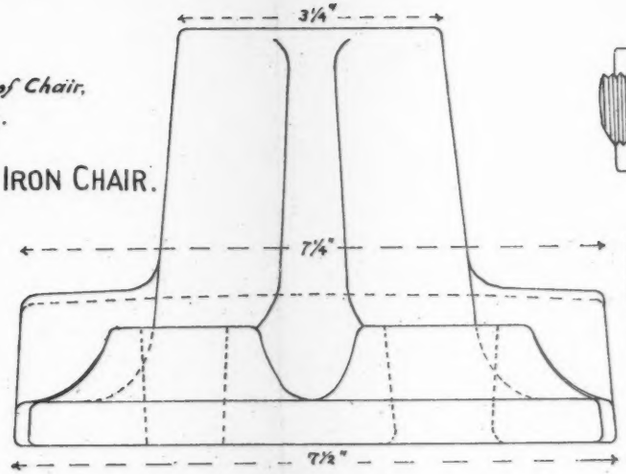


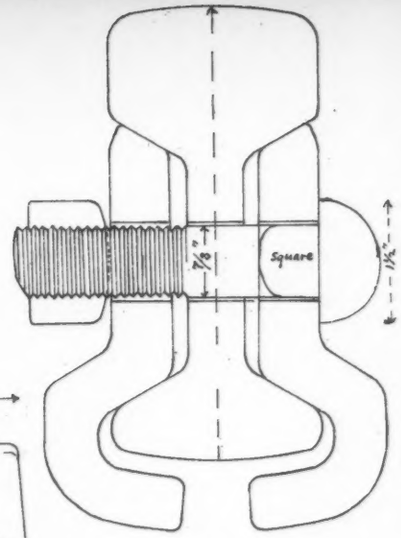
MIDLAND RAILWAY

PLATE LXII.
TRANS. AM. SOC. CIV. ENG'NS.
VOL. XVIII Nº 388.
TRATMAN ON ENGLISH
RAILROAD TRACK.

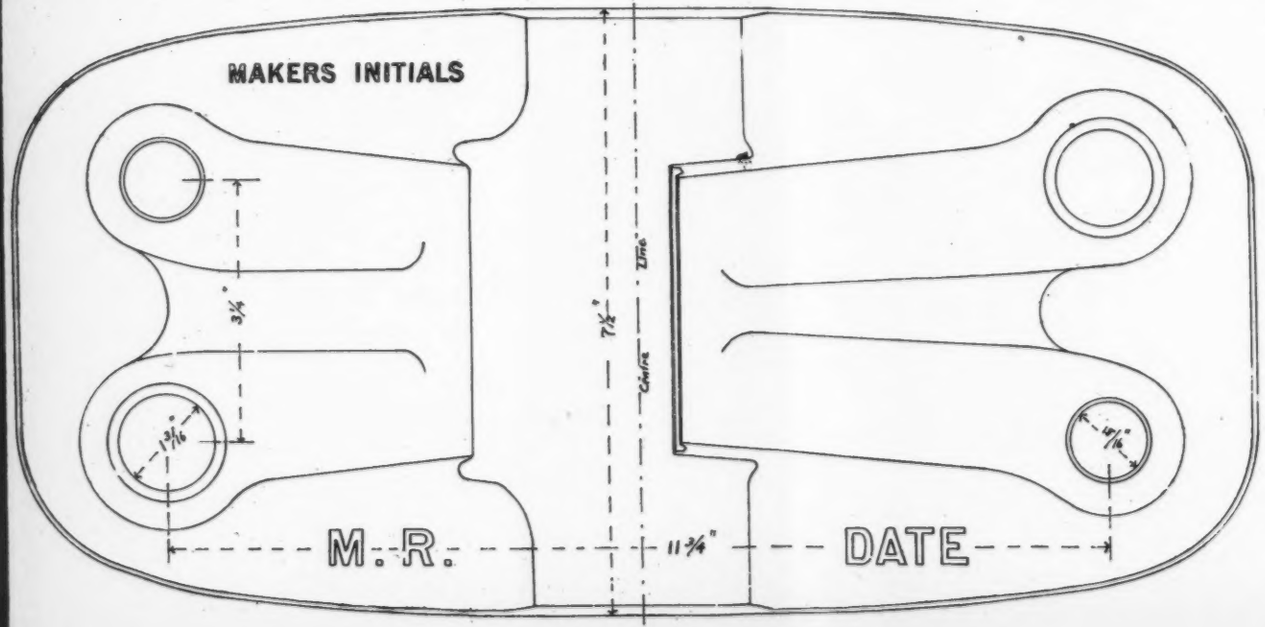
85 LBS. STEEL RAIL IN CAST IRON CHAIR.

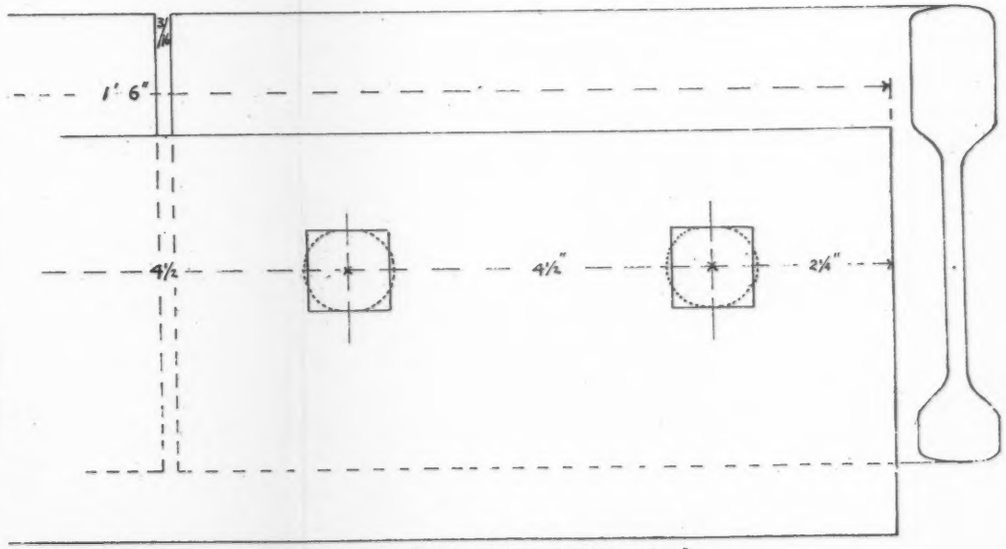






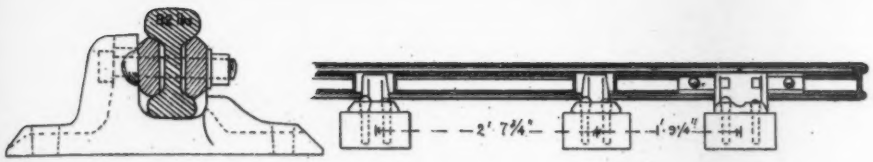
JOINT





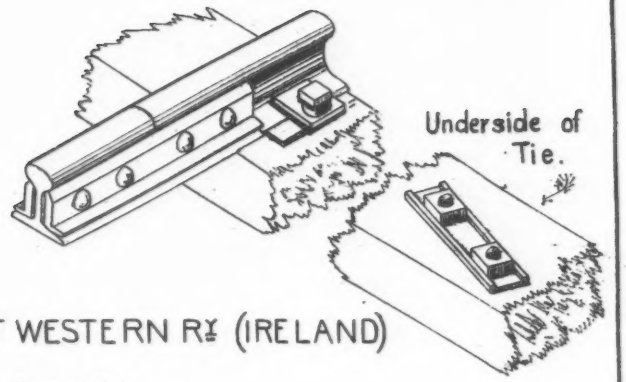
Holes in Rails, 1" x 1⅛"

Holes in Fish Plates, 1" x 1"



GREAT NORTHERN Rʸ

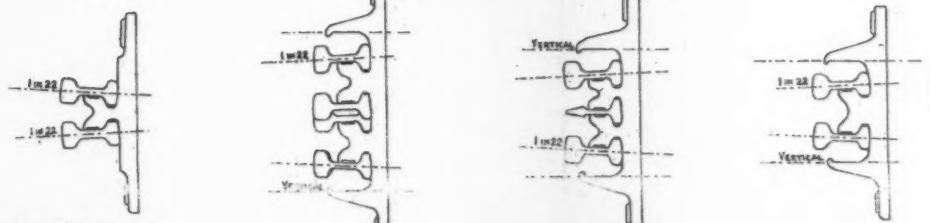
RAIL JOINT.



MIDLAND GREAT WESTERN Rʸ (IRELAND)

RAIL JOINT.

CROSS SECTIONS THRO' CENTRE OF CHAIRS.

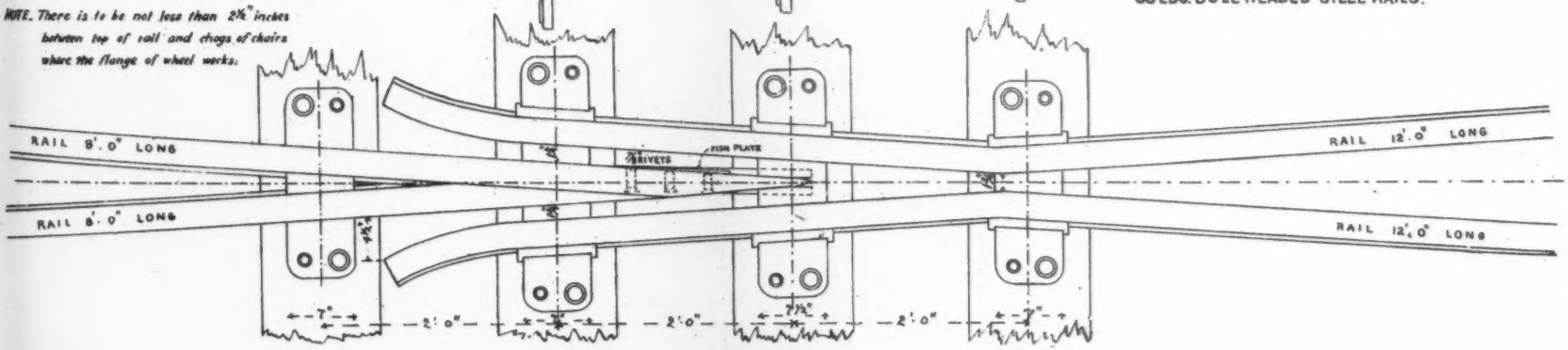


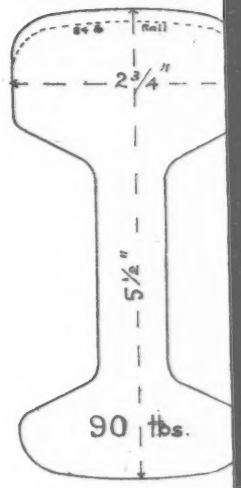
GREAT EASTERN Rʸ

Common Crossing 1 in 8.

85 LBS. BULL HEADED STEEL RAILS.

NOTE. There is to be not less than 2⅛" inches between top of rail and chogs of chairs where the flange of wheel works.





LONDON & NORTHWESTER

LIVERPOOL CENT

This line now laid with Bull-headed Rails.

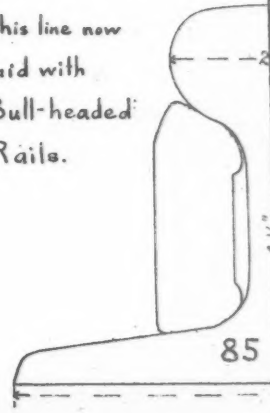
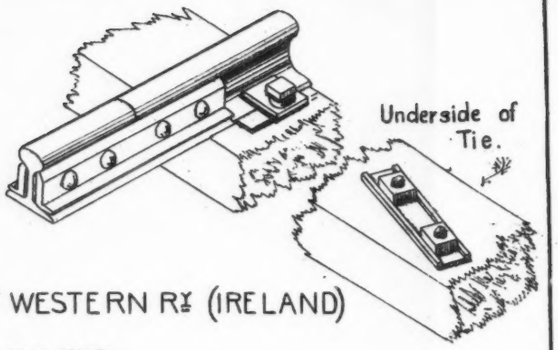


PLATE LXIII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XVIII Nº 388.
TRATMAN ON ENGLISH
RAILROAD TRACK.

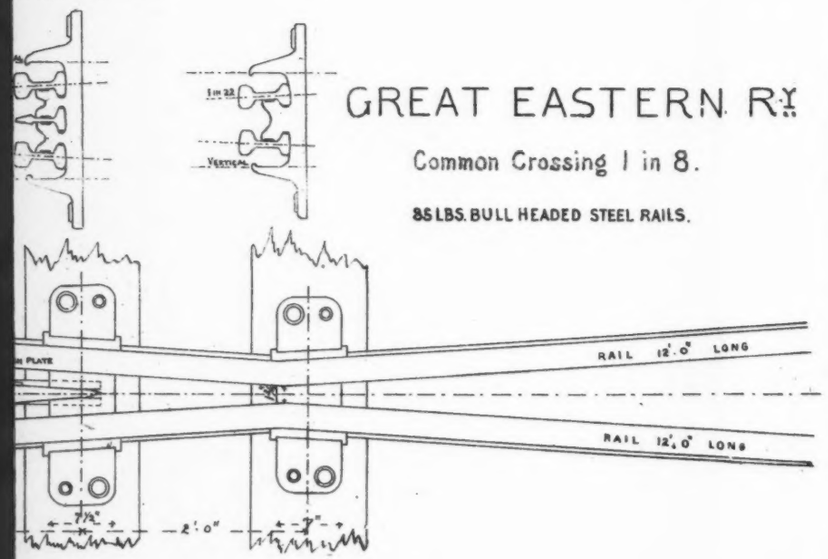


ERN Rʏ

MIDLAND GREAT WESTERN Rʏ (IRELAND)

RAIL JOINT.

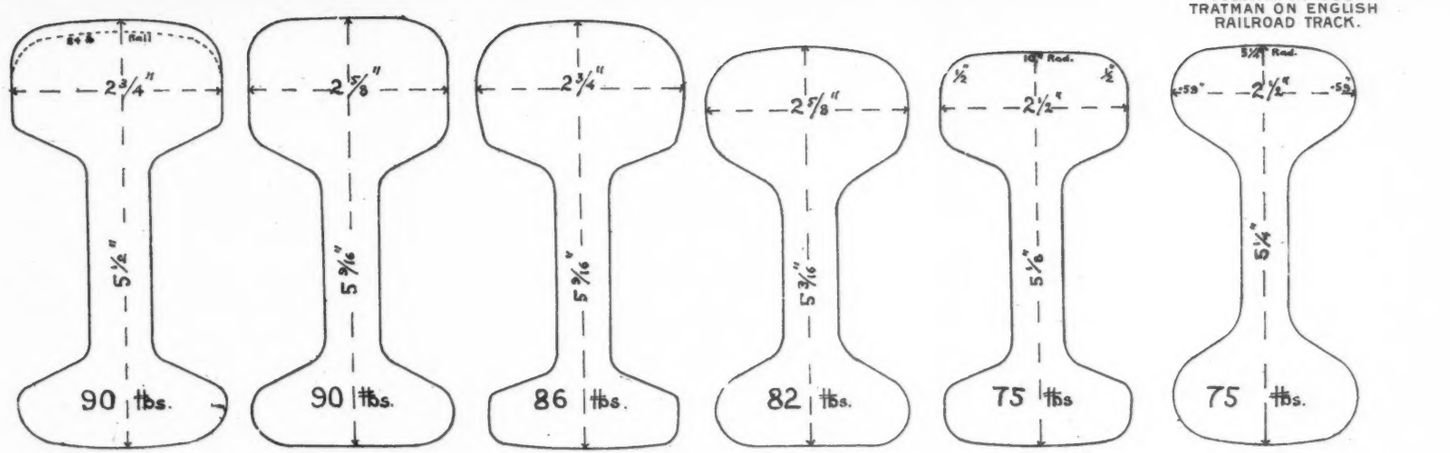
TRE OF CHAIRS.



GREAT EASTERN Rʏ

Common Crossing 1 in 8.

85 LBS. BULL HEADED STEEL RAILS.

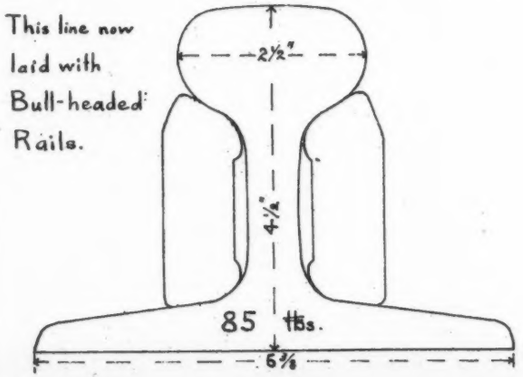


LONDON & NORTHWESTERN. | CALEDONIAN. | GREAT WESTERN. | GREAT NORTHERN. | GREAT NORTHERN (Iʀᴇ). | NEW SOUTH WALES GOVT.

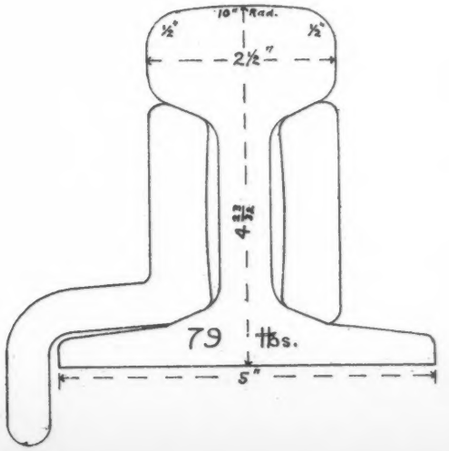
RAIL SECTIONS

LIVERPOOL CENTRAL STATION.

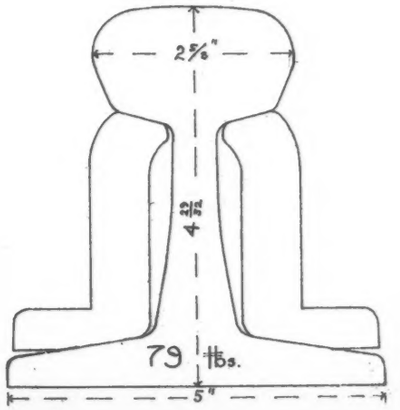
This line now laid with Bull-headed Rails.



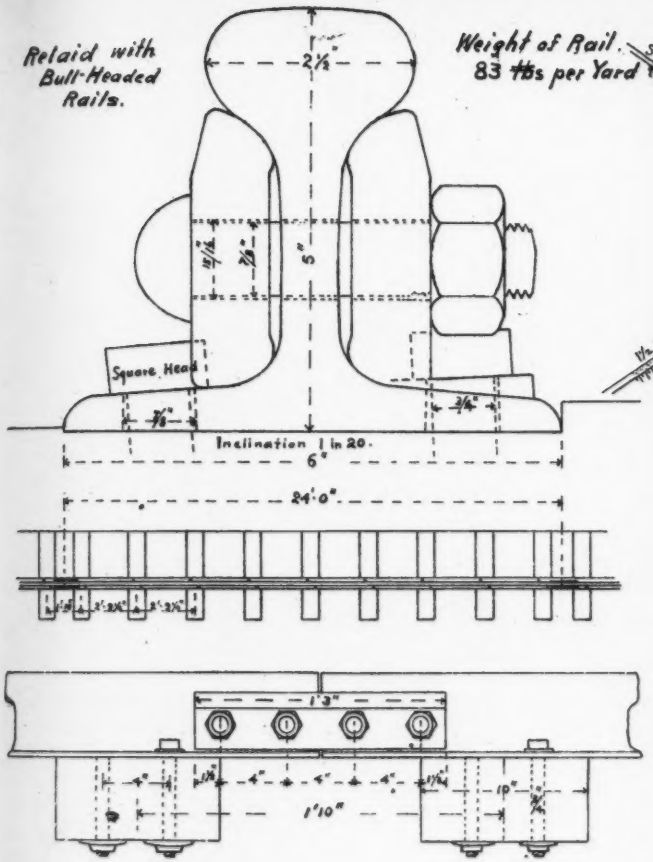
GREAT NORTHERN. (IRELAND).



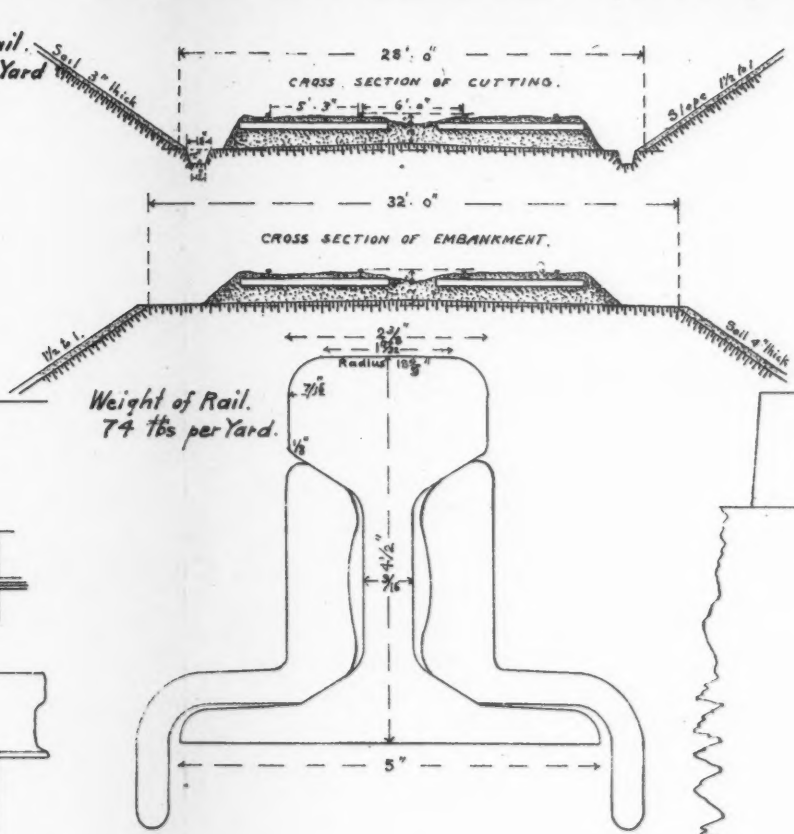
MIDLAND GREAT WESTERN. (IRELAND).



WEST RIDING & GRIMSBY. Rx



GREAT SOUTHERN & WESTERN Rx (IRELAND).



SEVERN & WYE & SEVERN

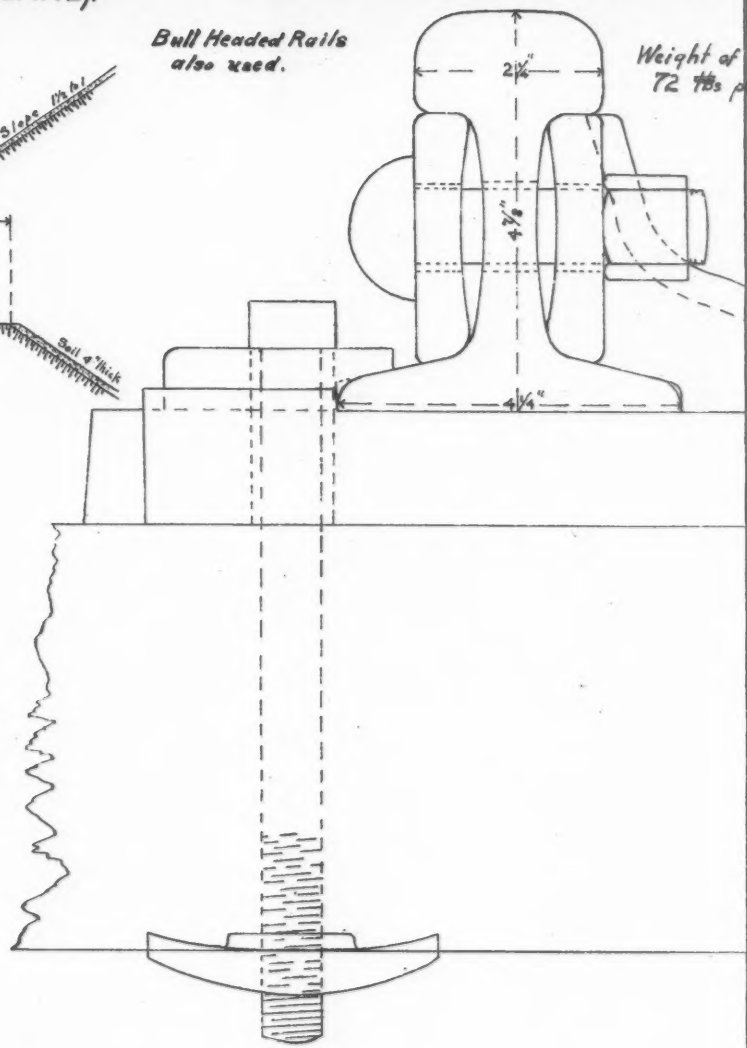


PLATE LXIV
TRANS. AM. SOC. CIV. ENG'NS.
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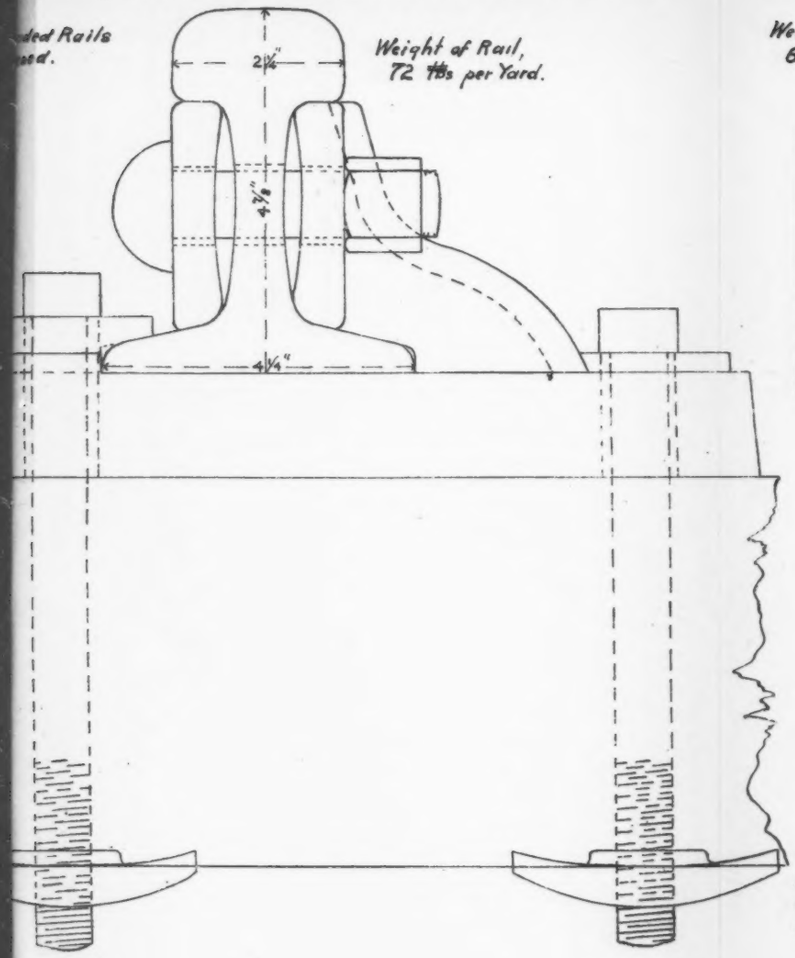
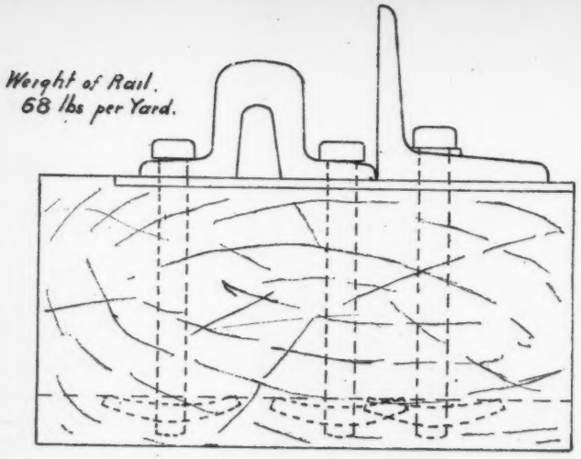
TRATMAN ON ENGLISH
RAILROAD. TRACK.

SEVERN & WYE & SEVERN BRIDGE Rʏ

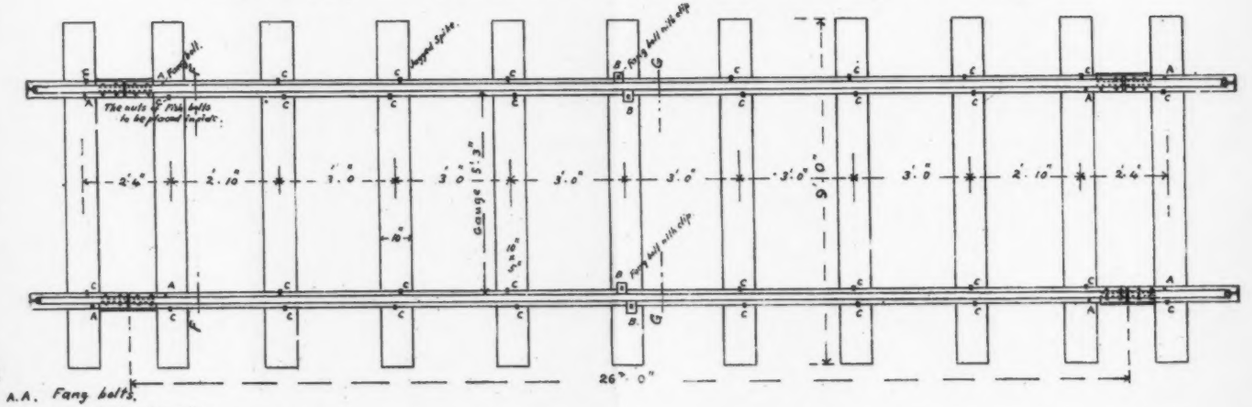




TRACK ON THE SEVERN BRIDGE.

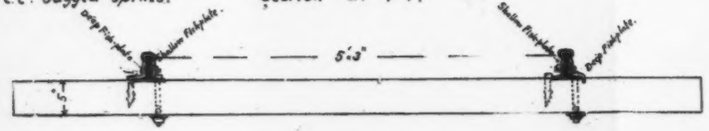
(HALF SIZE.)

GREAT NORTHERN Rʏ (IRELAND).

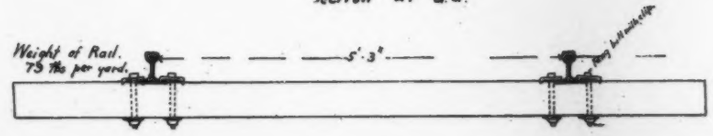


A.A. Fang bolts.
B.B. Fang bolts with clips.
C.C. Jagged spikes.

Section at F.F.



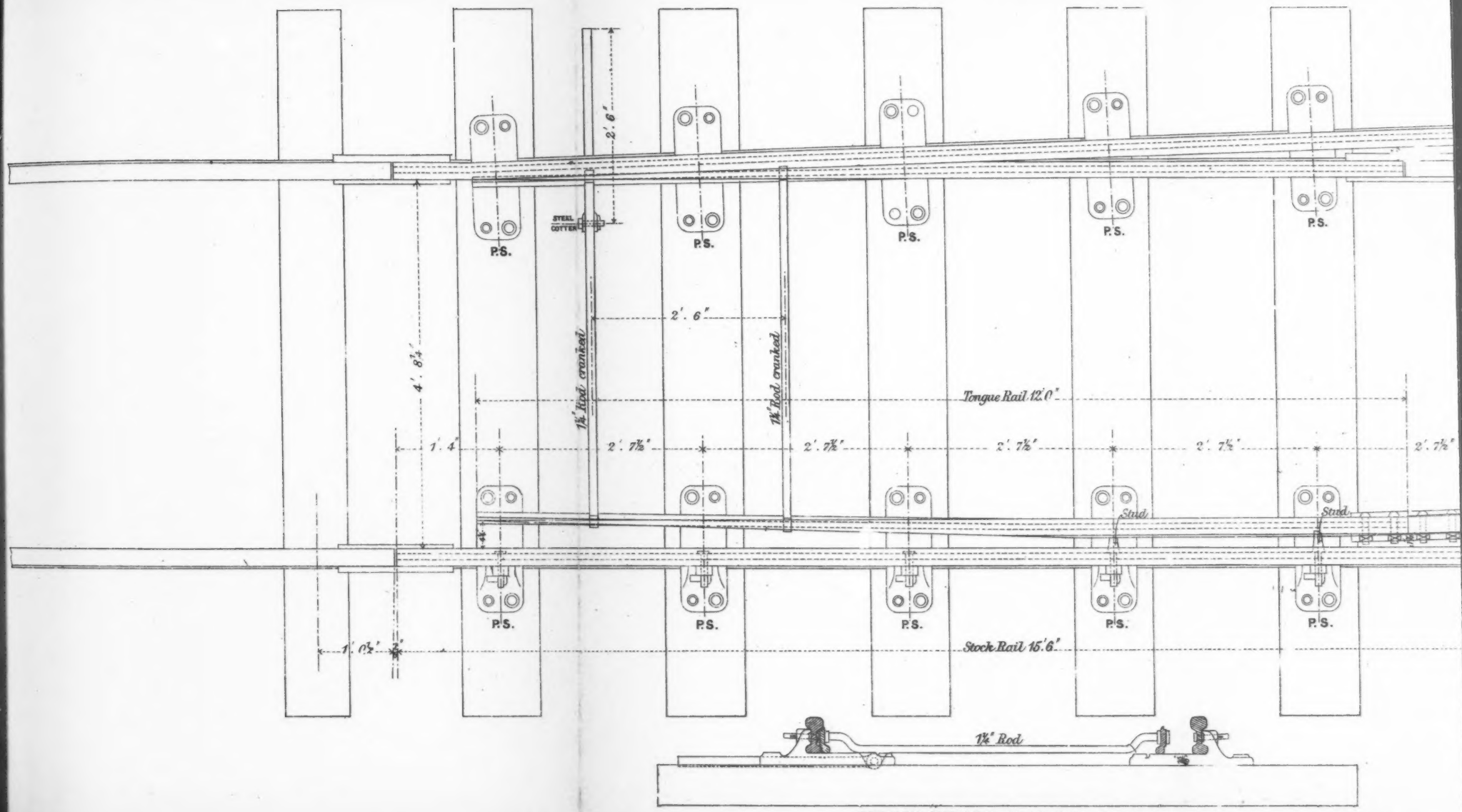
Section at G.G.



GREAT EASTERN RAILWAY

Points 12'. 0" Tongues.

85 LBS BULL HEADED STEEL RAILS



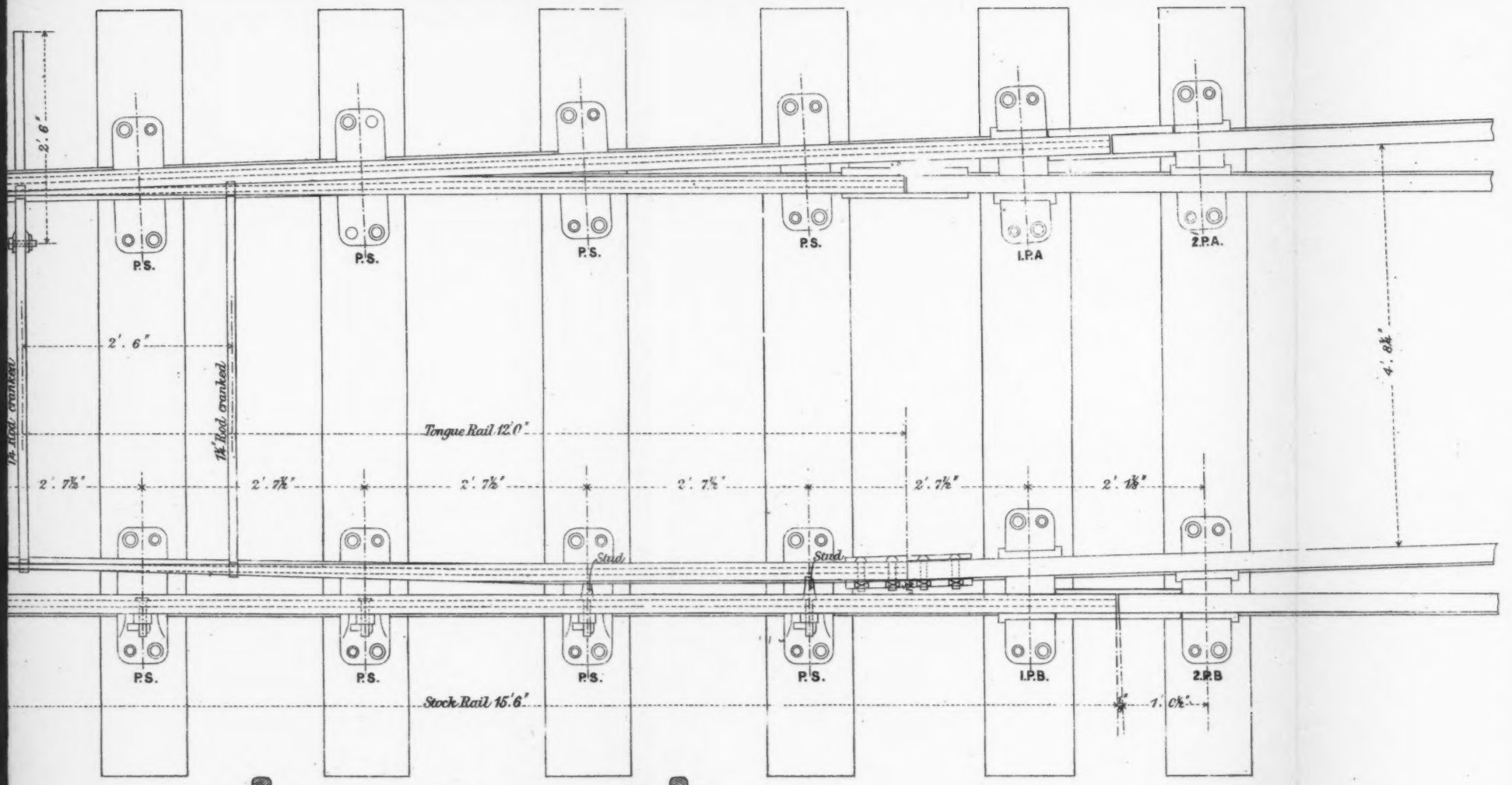
SECTION SHEWING CRANKING OF RODS.

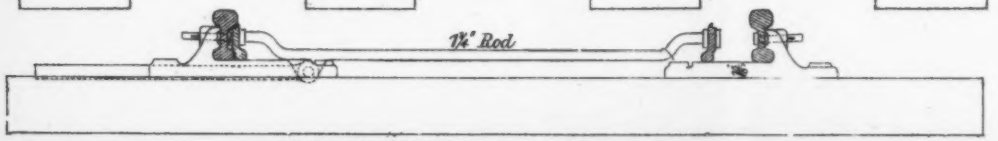
PLATE LXV
TRANS. AM. SOC. CIV. ENG'NS.
VOL. XVIII Nº 388.
TRATMAN ON ENGLISH
RAILROAD TRACK.

GREAT EASTERN RAILWAY

Points 12'. 0" Tongues.

85 LBS BULL HEADED STEEL RAILS

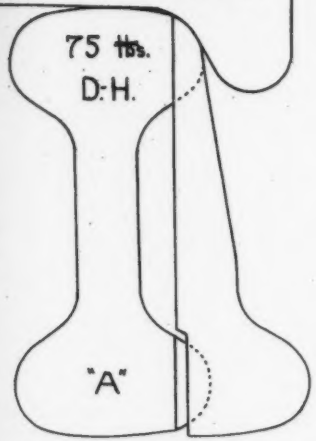




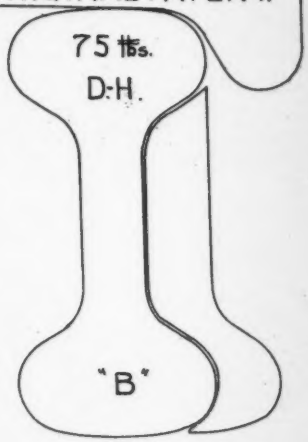
SECTION SHEWING CRANKING OF RODS.

PLATE LXVI
TRANS. AM. SOC. CIV. ENG'NS.
VOL. XVIII Nº 388.
TRATMAN ON ENGLISH
RAILROAD TRACK.

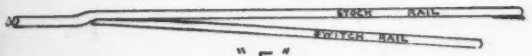
OLD SYSTEM.
NOTCHED STOCK RAIL.



WILD'S
ORIGINAL PATENT.

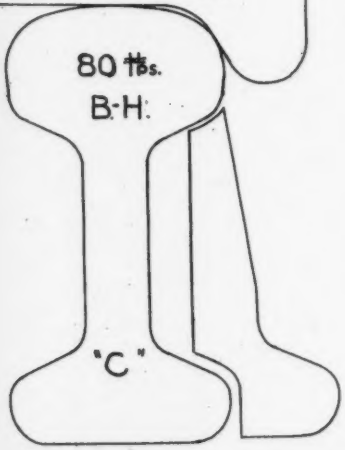


CRANKED STOCK RAIL.

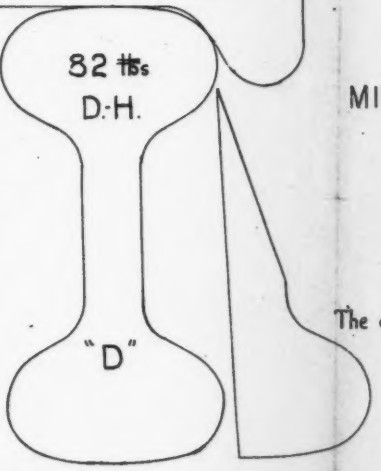


"E"

CALEDONIAN RY
PRESENT PRACTICE.



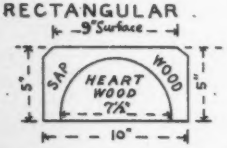
NORTH EASTERN RY
PRESENT PRACTICE.



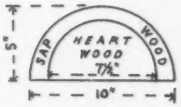
MIDLAND GREAT WESTERN RY (IRELAND).

TIMBER CROSS-TIES.

RECTANGULAR



HALF-ROUND.



The center of the Heart Wood must be within ½-inch of the under surface of the Tie.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

389.
(Vol. XVIII.—June, 1888.)

MAINTENANCE—EXPENSES OF TRACK ON WOODEN AND METAL TIES.

By J. W. POST, PERMANENT WAY ENGINEER NETHERLAND STATE RAILROAD COMPANY.

READ AT THE ANNUAL CONVENTION, JULY 2D, 1888.

WITH DISCUSSION.

Though the track of European railroads shows in material, construction and maintenance a great difference from the track on American lines, the following data concerning the use of steel cross-ties, gathered methodically since 1865 on the lines worked in Holland, Belgium and Germany by the Netherland State Railroad Company, may be of some interest to American railroad engineers.

The first trial of metal ties on the Netherland State Railroad dates from 1865, in which year 10 000 Cosijns ties were laid. In 1880 these ties, of a system now considered poor, had given satisfactory results as to the metal part during their fifteen years of service, but the oak blocks had to be frequently renewed. Moreover, the following considerations induced the company to search for a good metal tie:

First.—It was feared that prices of timber would gradually rise, owing to the increasing devastation of forests.

Second.—Even with the wood deemed best for ties, viz.: oak, it was difficult to secure satisfactory results; some lots of oak ties, severely in-

spected, appeared first-rate when new, but had to be renewed after only one year of service. The time of felling seems to be of great importance, and cannot be determined at the moment of purchase even by the severest inspection.

Third.—Even the best methods of impregnating proved unreliable; of ties coming from the same boiler some were quite saturated, others only on the surface; some lasted one year only, others twenty years. Uniformity in this respect is desirable for the track.

Fourth.—No timber merchant guarantees his ties; whereas steel ties are generally guaranteed for two years.

Fifth.—There is a great loss of interest during the time timber ties are piled in order to dry; whereas metal ties are often in the track before being paid for.

Sixth.—There is a great loss of timber ties by bursting, caused by sunshine, water, frost, driving the spikes, etc.

Seventh.—Timber ties being heavier than metal ties, the transport to the place where they are put in the track is more expensive.

Eighth.—The difficulty and cost of the respiking and readzing of timber ties, and of the replacing by new ones, increases with the daily number of trains. Ties of more durable material are desirable also from that point of view.

Ninth.—The selling price of old metal ties is considerably higher than the price of old timber ties.

Tenth.—A calculation* of the total annual sum required for purchase, laying, maintaining and renewing tracks on timber and on metal ties gave a favorable result for the metal.†

All these considerations induced the company to charge the writer in 1880 to study, both at home and abroad, the different systems of metal ties then in use, both from the point of view of manufacture and of maintenance, and to propose a method of trial enabling the company to get the most complete information possible on the subject.

This charge resulted in the following different systems of ties and fastenings being laid in the track from 1880 to 1888:

In 1881	4 133	ties, type	I.
" 1882	4 001	"	II.
" 1883	2 089	"	III.
" 1883	2 090	"	IV.
" 1884	11 680	"	V.

* For methods of calculation see valuable report to American Society of Civil Engineers, June, 1885, on the "Preservation of Forests."

† Many important improvements introduced since have increased the advantage of metal over timber.

And from 1885 to 1888, about 126 000 ties, types VI, VII, VIII and IX, making about 150 000 ties of ten different types (including Cosijns). Of each of the types, trial lengths, under different circumstances of grades and curves, were put under special observation, every hour of maintenance-work and every renewed piece being scrupulously noted. As a base of comparison 1 120 first-rate new oak ties were laid in the track, the rails being fastened with the ordinary spikes.

At the same time different systems of fastenings were tried on the metal ties.

The Plate No. LXVII, shows the principal features of each of the types of ties and fastenings put under observation. By trying the best improvements in shape, material and manufacture, and by eliminating every year the faults of the preceding types, the writer gradually arrived at types VIII and IX of ties and type *C* of fastenings, which types having shown great advantage in every respect over the preceding types, have now been adopted as standards for this railroad.*

Types VI, VII, VIII and IX are in mild steel rolled to a variable section, strengthening at rail seats and tilt, 1.20 being obtained directly by rolling, thus preserving the steel from damage at the vulnerable spot (rail seats) by bending or pressing. These ties weigh 50 to 55 kilogrammes each, corresponding to 57 to 63 kilogrammes per tie of uniform section BB (economy 15 per cent.). Type VI, without waist, like all preceding types, I to V, had not quite the same stability as types VII, VIII and IX have; indeed, this reduction of breadth in the middle causes the principal reaction of the ballast to work at the rail seats, eliminating the balancing action of the track which takes place when the support is in the middle, particularly on badly ballasted roads or with neglected packing. Moreover, the increased height at the center gives greater rigidity to the tie.

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* Other railroads have, to their great satisfaction, followed this example. A total of about 457 300 ties (about 23 800 tons) of the Post-types VI, VII, VIII and IX is now in service on different lines of Holland, Belgium, France, Germany, Switzerland and Asia (colonies). About 272 700 more (about 12 700 tons), comprising the narrow gauge and rack road ties for Sumatra, are ordered and being manufactured now, making a total of about 730 000 ties (or 36 500 tons). See on this subject:

(*a.*) Mr. Bricka's official report to the French Minister of Public Works.

(*b.*) Mr. Kowalski's official report to the Milan Railroad Congress, 1887.

(*c*) Report of Vincennes Exhibition, 1887, highest award to Netherlands State Railroad Company and to the writer.

(*d.*) Annual Report, 1887, of the French Society for the Advancement of Industry; silver medal awarded to the writer.

The wedge-waisted tie VII is, unfortunately, of difficult manufacture, and so types VIII and IX are practically esteemed the best, and all agree that they give remarkable results. The ends are closed (Figs. 2 and 3), and grip projects downwards 2 inches into the ballast. The tests prescribed for inspection are very severe (see Figs. 4 and 5). The author executed a series of tests to establish whether annealing the ties after punching the holes does pay or not. Figs. 6 and 7 show the result; his conclusion was, that with mild steel annealing is not necessary, but is desirable if it can be done at small expense.

The ties are tarred if they have to remain a long time beside the track. The price, including two years of guarantee, varies from 22 to 26 francs per ton.

The fastenings, type *C*, show the following improvements, gradually introduced and tried by the writer. The surface of nuts and clips is roughened to facilitate the grip of the Verona nut lock. The nuts are indented for this purpose (Figs. 8 and 9). The clips, if rolled (mild steel annealed), get three fillets (Fig. 9) for the same reason; if stamped (iron or mild steel), they are indented like the nuts (Fig. 10). In both cases the clip has a large contact with the surface of the tie in order to reduce the wear. For the same reason the head of the bolt (iron or soft manganese steel) is large (Fig. 11). The bolt must not be less than 1 inch diameter. The collar of the bolt, which is eccentric, to enable widening of gauge on curves by turning the bolt 180 degrees, fits tight into the tie hole; this hole being rounded in the corners to avoid cracks, the bolt collar is rounded accordingly. The Verona nut locks (Fig. 12) are of the very best quality, severely tested as to elasticity and sharpness of points, and are guaranteed. The price of these improved fastenings does not exceed 24 francs per tie.

The statistical results as to cost of maintenance gathered to January 1st, 1888, on twenty-four trial lengths, are shown in the accompanying table. Columns 1 to 14 give the particulars of sections, condition of laying, types, etc., and columns 15 to 22 the expense of maintenance per day and per kilometer in francs.

The statistical data gathered to January 1st, 1887, and the close and scrupulous observations of the trial divisions, allowed the company to report seventeen conclusions to the Milan Railroad Congress in 1887. The service from January 1st, 1887, to January 1st, 1888, having fully confirmed the opinions of the company on these seventeen points, the

following conclusions are still applicable to the statistical data gathered to January 1st, 1888, as contained in the accompanying table:

1. Trials 11 and 14 are on curves of 350 meters radius and 16 millimeters per meter grade. Oak ties occupying this place previously had to be respiked every year, causing great cost of maintenance; the rail flange cut the spikes 3 to 4 millimeters, thus giving every year a gauge widening of 6 to 8 millimeters. Several ties of type III, on the contrary, taken from the track for inspection after 1 553 days of service, showed only a widening of 2 millimeters, the exterior bolts, type *A*, being worn only 1 millimeter by the rail flange. The tie surface only showed a slight amount of corrosion, and the holes were not in any way enlarged or ovalized. Considering the unfavorable conditions under which these ties were, these are very good results; in no year did the expense amount to 2 francs per day kilometer, and the average day kilometer is only 1.39 and 1.40 francs (columns 18 to 22).

2. Trials 3 and 9 being on marshy ground, the result may also be considered as favorable; in no year as much as 2 francs per day kilometer, and average day kilometer francs 0.95 and francs 0.88 (columns 15 to 22).

3. As to consolidation (about 2 300 days), the only trials comparable to the base trial No. 1 (oak ties) are trials 2, 3, 4 and 5. Though two of these four trials are under unfavorable conditions, there is no sensible difference between the average day kilometer of trials 2, 3, 4 and 5, and the day kilometer (francs 0.605) of trial 1, a very favorable result indeed, considering the following facts:

(*a*). Type I is what we now consider a poor system, each of types II to IX being great improvements. Had one of the more perfect types been used on these trials, still better results would have been obtained.

(*b*). Respiking and readzing of the oak ties of trial 1 had begun in 1886, and has to be continued in 1888 and following years, increasing the cost of maintenance with the age of the wood.

(*c*). With the trials on metal ties, on the contrary, there is a tendency shown of a decrease of expense as the permanent way becomes set.

(*d*). On trial 1 only ten oak ties had to be replaced by new ones since 1881; this renewing, however, will go on increasing with the age of the wood, thus increasing, apart from the

cost of purchase, the daily expense (work) of trial 1. The renewal of ties on the other twenty-three trials, on the contrary, was *nil* since 1881 (not one metal tie being broken), and will be *nil* for many years.

4. The day kilometer of trials 6, 7, 8, 12 and 17 does not exceed francs 0.88; those of trials 10, 13, 15, 16, 18 and 19 are below francs 0.60, though these eleven trials date only from 1883 and 1884.

5. The time of observation for types VI, VIII and IX (trials 20 to 24), has been too short to form any definite idea of the mean day kilometer; meanwhile everything tends to show that these types will give even far better results than types I to V.

6. The average expense for laying and maintaining the twenty-three trial-lengths, 2 to 24 has not been greater than would have been occasioned by the timber ties laid on the same places. The supplementary expenditure for these trials, apart from the trouble of statistics, etc., is therefore *nil*.

The close observation of the permanent way and of the manufacture of ties and fastenings led the company to the following conclusions:

7. A part of the road near Liege, twenty-five trains daily, curve of 530 millimeters radius, 16 millimeters per meter gradient, after having been carefully packed, was left for forty months without any other work than occasional nut-tightening. This shows that a good road, with steel ties, once properly packed, requires no more scrupulous attention and maintenance than one laid with timber ties; on the contrary, it would have been dangerous to have left a track situated as this was, and laid with timber ties, for a period of three and a half years.

8. The diagrams of the self-registering gauge-measure show that the gauge is much more regularly kept on metal ties than on timber (even new oak) ties.

9. The position of the rail, which often changes on timber ties, is not variable with the metal ties.

10. The lateral displacement of the track is insignificant with metal ties, even on curves of short radius, providing that the tie is closed at the end.

11. The breadth of the ballast bed may be made a little smaller with waisted metal ties (Types VII, VIII and IX) than with ordinary metal or timber ties.

12. The respiking and readzing of trial necessitated to 1888 the re-

placing of 2 bearing plates and 1 081 spikes by new ones. The renewal of fastenings on the metal ties is insignificant, especially with Type *C*.

13. Iron is not recommended for metal ties; mild steel is superior to it in every respect, viz., manufacture, inspection, rigidity and durability.

14. Alternating joints have given satisfactory results, especially in curves of short radius.

15. Suspended rail-joints have given the best results on metal ties, providing the angle splice-bars be strong and the distance between joint-ties small.

16. Types VII, VIII and IX fulfill all conditions for properly imbedding the tie. If the packing is done properly, and does not exceed 1½ feet from each side of the rail, the track can never become balancing, through the ballast working towards the middle of the tie and leaving the ends unsupported, for the shape of the tie drives the ballast towards the rail seats, both transversely and longitudinally (see Fig. 1 and section under type *C*.) Generally the ballast soon forms into a compact cake, adhering to the interior of the tie, thereby augmenting both the base and the mass of the track.

17. The track men, who generally abhor novelties, have soon learned, owing to practical instructions, to appreciate the steel ties and to make an excellent track with them.

The company closed these seventeen conclusions by quoting at the Milan Congress the following statement from the annual report of Mr. Charles Renson, Resident Engineer of the Liegeois section, which will be received with great appreciation on account of the distinguished and impartial manner in which this engineer has organized the trials of metal ties on that section:

"A single track with ties, Type VIII or IX, having twenty-five trains per day with curves, gradients, ballast, etc., as the Liege-Hasselt section, can be, after four years of consolidation, maintained in proper order at the rate of one hundred working days per year—kilometer. A gang of four men, working two hundred and fifty days a year, of which fifty days are given to other work, are able to maintain in good condition 8 kilometers of permanent way."

The Netherland State Railroad Company, having experienced the great advantage of practical experiments made on trial sections of track, has continued experiments as follows, in order to gather information on other points.

Between Tilburg and Breda, four parts of equal length were laid in 1886 on the same track, to compare the cost of maintenance and of renewal between:

1. Ordinary steel rails (33 kilograms per meter) on timber ties.
2. Heavy steel rails (40 kilograms per meter) on timber ties with two Post's steel, toothed bearing-plates on every tie.
3. Heavy steel rails (40 kilograms) on heavy Post steel ties.
4. Ordinary steel rails (33.7 kilograms per meter) on ordinary Post steel ties.

The time of observation is yet too short for any conclusion.

Between Tilburg and Breda, four parts of equal length are being laid now in the same track to compare the cost of maintenance and of renewal between:

1.	Ordinary steel rails	on	10	timber ties,	per	9 meters of track.
2.	"	"	11	"	9	"
3.	"	"	12	"	9	"
4.	"	"	12	"	9	"

—with alternating joints.

Between Weurne and Helmond the same four comparative trial lengths are being laid on ten, eleven and twelve Post steel ties per 9 meters of track.

The information gathered by these methodical researches will be of great value; not only for the Netherland State Railroad but for railroading generally; the best remedy for scanty net earnings being a reduction of the expenses of maintenance and renewal.

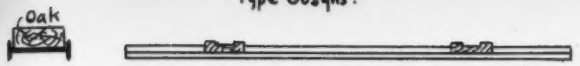
Table of Cost of Maintenance on Trial Tracks with Wooden and Metal Ties, Netherland State Railroad Company.

Vol. XVIII, p. 260.

Trial Number.	Trains per day.	Section of Line.	From (Kilom.)	To (Kilom.)	Gradient in millimeters per meter.	Radius of Curves in meters.	Length of Trial in meters.	Number of Ties.	Types. Ties.	Types. Fasten'gs.	When Laid.	Date when Observation Commenced.	Number of days in service. From beginning observation to Jan. 1, 1888.	Number of days in service. 1887.	Cost of Maintenance in francs per kilometer per day. 1881.	1882.	1883.	1884.	1885.	1886.	1887.	From beginning observation, 1888.
1	25	Liége-Tongres	15.620	14.612	12	500	1.008	1 120	Oak.	Spikes.	1881	July 1, '81	2 375	365	0.159	0.217	1.226	0.396	0.493	1.101	0.423	0.605
2	25	Liége-Tongres.....	16.666	15.620	12	750 straight	1 046	1 133	I.	A	1881	"	2 375	365	1.120	0.423	0.576	0 195	1.086	0.538	0.842	0.650
3*	25	Bilsen-Hassett.....	41.093	40 170	1.2	straight	0.923	1 000	I.	A	1881	Sept. 1, '81	2 313	365	1.930	0.829	1.884	0.256	0.901	0.383	1.135	0 952
6	25	Liége-Tongres.....	7 946	7.432	16	1 000	0.514	600	II.	B	1882	Jany. 1, '83	1 826	365	.....	.....	1.214	0.489	0.638	1.112	0.552	0.801
7	29	Liers-Flamalle.....	1.831	1.393	level	1 000	0.438	500	II.	B	1882	"	1 826	365	.....	.....	1.582	0.277	1.160	0.494	0.573	0.817
8	25	Tongres-Bilsen.....	25.031	24.570	8	straight	0.461	500	II.	B	1882	"	1 826	365	.....	.....	1.676	0.533	1.253	0.118	0.046	0.725
9*	25	Bilsen-Hassett	43.625	43.349	4	straight	0.276	300	II.	B	1882	"	1 826	365	.....	.....	1.687	0.861	0.953	0 278	0.625	0.881
11	25	Liége-Tongres.....	3.790	3.640	16	350	0.150	201	II.	B	1883	Oct. 1, '83	1 553	365	.....	.....	0	1.084	1.974	1.187	1.660	1.389
12	25	" "	12.707	12.528	13	500	0.259	300	II.	B	1885	"	1 553	365	.....	.....	0	0.891	0.465	0.264	0.746	0.587
14	25	" "	4.002 / 3.640	3.790 / 2.836	16	350	1.016	1 328	III. & IV.	A	1885	"	1 553	365	.....	.....	0	1.647	1.792	0.867	1.610	1.392
17	25	" "	12.528	12.315	13	500	0.215	250	IV.	A	1883	"	1 553	365	.....	.....	0	1.132	1.111	0.498	1.000	0.879
21	25	" "	4.412 / 4.7 5	4 302 / 4.748	16	530	0.117	200	VI.	C	1885	April 1, '85	1 005	365	.....	.....	.....	.....	0.036	0.078	0.983	0.495
22	25	" "	8.000	9.000	16	1 000	1 000	1 081	VI.	C	1887	June 1, '87	214	214	.....	.....	.....	.....	.....	.....	0	0
4	14	Hassett-Wychmael ..	22.238	21.130	2 9	straight	1.108	1 200	I.	A	1881	June 15, '81	2 390	365	0.6635	0.595	0.614	0.198	0.156	0.418	0.297	0.407
5*	14	Wychmael-Achel....	32.673	31.940	3 4	"	0.733	800	I.	A	1881	Sept. 1, '81	2 313	365	1.584	1.027	0.790	0.326	0.536	0.569	0.227	0.632
10	14	Hassett-Wychmael...	8 408	7.301	3.9	"	1.107	1 200	II.	B	1882	Jany. 1, '85	1 826	365	.....	.....	1.077	0.475	0.329	0.503	0.595	0.596
13	14	" " ..	1.562	1.218	6 5	500	0.344	400	II.	B	1883	Sept. 15, '85	1 569	365	.....	.....	0	0.433	0.438	0 879	0.583	0.543
15	14	" " ..	1 218	0 765	6 5	500	0.453	500	III. & IV.	A	1883	"	1 569	365	.....	.....	0	0.246	0.412	0.258	0.429	0.313
16	14	Achel-Eindhaven....	47.334	47.795	0.8	2 000	0 461	500	III.	A	1883	March 1, '84	1 401	365	.....	.....	.....	0.311	0.143	0.329	0.802	0.421
18	14	" "	47.795	48.256	level	straight	0.461	500	IV.	A	1884	"	1 401	365	.....	.....	.....	0 299	0.372	0.553	0 651	0.471
19	14	" "	46.868	47.334	0 8	"	0.466	505	V.	A	1884	"	1 401	365	.....	.....	.....	0.551	0.897	0.277	0.492	0.554
20	14	" "	52 709	52.032	1	2 000 straight	0.677	735	VI.	C	1885-'86	June 1, '86	579	365	.....	.....	.....	.....	.....	0.144	0.252	0.212
23	14	" "	57.342.50	57.425 9	1	2 000	0.083.40	93	VIII.	C	1887	Sept. 1, '87	122	122	.....	.....	.....	.....	.....	.....	0	0
24	14	" "	57.425.95	57.509 10	1	2 000	0.083.15	93	IX.	C	1887	"	122	122	.....	.....	.....	.....	.....	.....	0	0
Col.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

Remarks.—These trial-lengths are on single track road. 1st group, 25 to 29 trains per day; 2d group, 14 trains per day.
Rails; 38 kilograms per meter; steel angle splice bars. Ballast—Gravel. sand and cinder.
Heaviest engine on these lines 50 tons, with 13½ tons on the heaviest axle } speed up to 50 miles per hour (on some parts 60 miles per hour.)
" other " 68 " " 13.9 " " " " }
A day's maintenance per man costs 2.19 francs; the results of Cols. 15 to 22 may be transformed into days by dividing by 2.19.
The figures in Cols. 15 to 22 give the expense for work of maintenance, not the expense for purchase of new spikes, bolts. etc.
Not one of the metal ties in this table, nor of the 124 000 steel ties in use on other lines of the Netherland State Railroad Company, has broken in the track.
* Marshy ground.

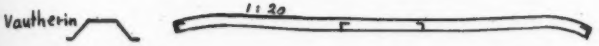
Type "Cosijns"



Section of tie in Trial N°1

I. Iron. 40kg.

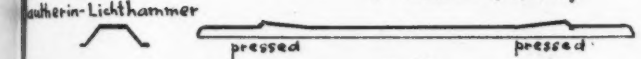
II. Iron 47.2 kg.



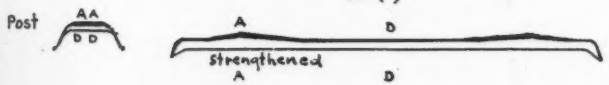
III Mild steel ; 50 kg.

IV. Mild steel; 52 kg.

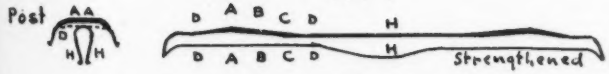
V Mild steel; 43.4 kg.



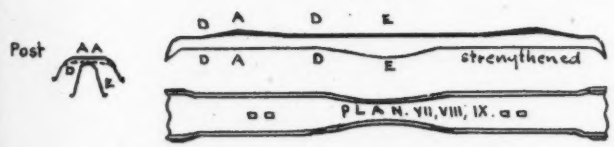
VI. (*)



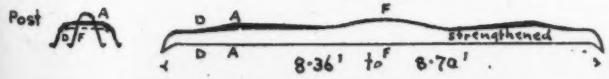
VII (*)

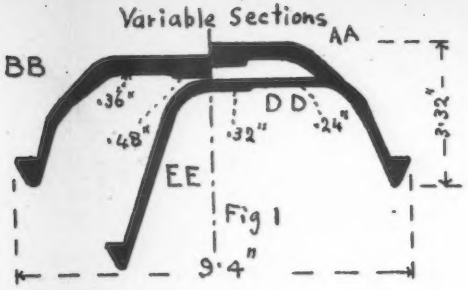


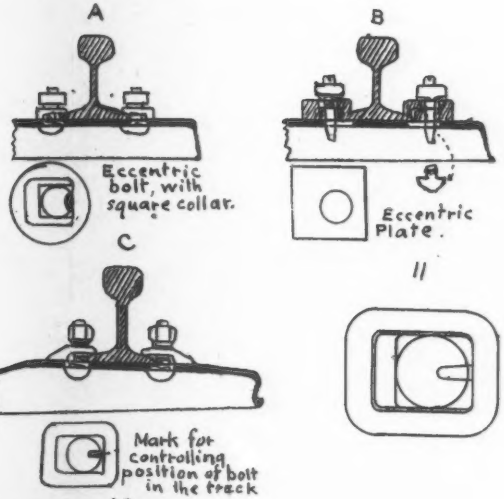
VIII (*)



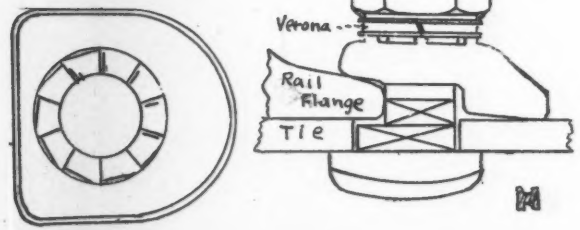
IX (*)



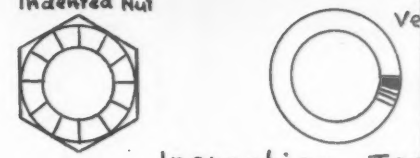




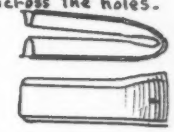
10 Stamped indented clip



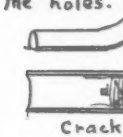
8 Indented Nut



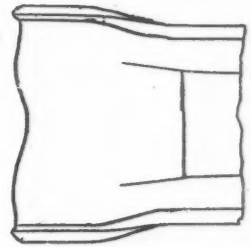
6 Annealed tie bent cold across the holes.



7 Un-annealed bent cold acro the holes.



2 End of Post steel ties VI, VII, VIII and



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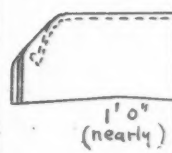


(*) Types VI, VII, VIII and IX are in Mild Steel able section, strengthening at rail seats and tilt 1: rolling. Weight 50 to 55 kg. per tie, correspon 63¼ kg. per tie, of uniform section BB, econom

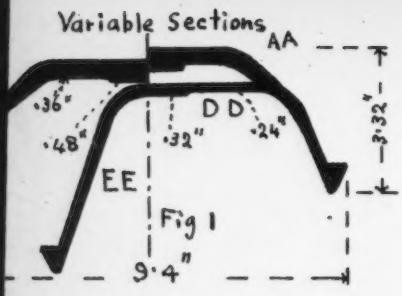
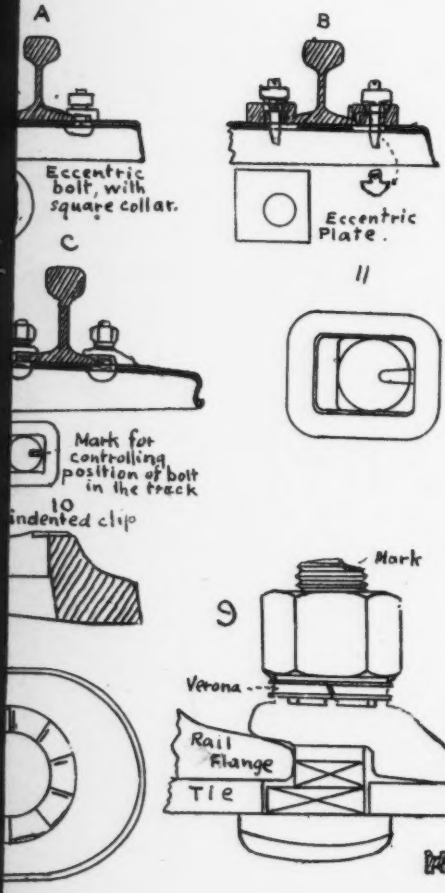
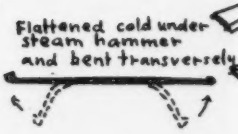
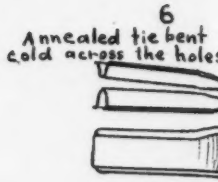
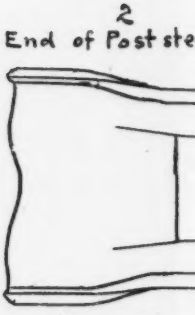


Fig 1









(*) Types VI, VII, VII
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PLATE LXVII
TRANS. AM. SOC. CIV. ENG'NS.
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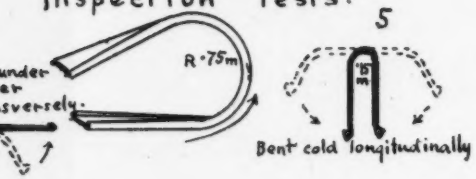
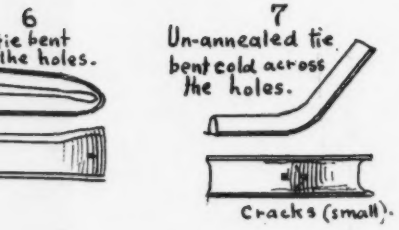
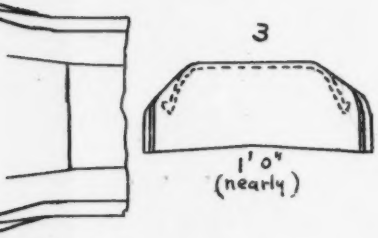
POST ON METAL
RAILROAD TIES.

Inspection Tests.





2
Post steel ties VI, VII, VIII and IX.



VI, VII, VIII and IX are in Mild Steel, rolled to varin, strengthening at rail seats and tilt 1:20, obtained by Weight 50 to 55 kg. per tie, corresponding to 57½ to per tie, of uniform section BB, economy (15%)

DISCUSSION.

E. E. Russell Tratman, Jun. Am. Soc. C. E.—Having received from Mr. J. W. Post, only a few days before the Convention, the paper on "Maintenance Expenses of Track with Steel and Wooden Ties, on the Netherland State Railroad," which I have transmitted to the Society by request of Mr. Post, I had not time to give as much attention as I would like to have done to this discussion.

The subject of metal railroad ties is one in which I take very much interest, and for some time past I have been engaged in making extensive investigations and collecting information with regard to practice and experience in foreign countries. In making my investigations I have been surprised at the great extent to which metal ties have been actually adopted for service, for while I knew that experiments had been made in many countries, in some cases on a quite extensive scale, I had no idea that, as a result of some of these experiments, many railroads had practically adopted these ties for regular use; this, however, I found to be the case, and several European railroad companies are now gradually substituting metal for wooden ties on their systems. I think few engineers who have not paid especial attention to this matter, realize that metal ties are in actual service, the general impression seeming to be that while many experiments have been made and are still being continued, yet that no practical results have been obtained. To this lack of appreciation of the results of foreign experience, may be attributed to a considerable degree, I think, the general indifference of American engineers to the question of metal track. The fact that the question of the future timber supply is one of serious import, does not seem to be realized, although the reports of the Forestry Division of the United States Department of Agriculture show that use and waste are playing havoc with a supply that cannot, under the present system (or want of system) of forestry in this country, be renewed in proportion to the demand. It has always seemed to me surprising that American engineers, who are usually in the van of any great step in the profession, should have paid so little attention to this very important matter; important both as to the financial economy and the practical efficiency of the track. In my opinion steel ties should be used as the standard for first-class track, and not merely as a substitute for timber, when the latter becomes scarce or expensive. For instance, on such a road as the projected New York and Boston Rapid Transit line, which is intended to be an independent line, and which will probably, when it materializes, start out with a heavy and rapid traffic, steel ties should be laid down in the first place. The same holds good for existing trunk lines, on which steel ties should be introduced, as an advancement in railroad engineering and a step towards economy.

Taken as a whole, the results of experience have been satisfactory, and the type which has been found to be the best is the cross-tie of the familiar reversed trough section. Cast-iron "bowl" sleepers are much used in new countries, and longitudinal iron sleepers are still used to some extent in Austria and Germany, but the cross-tie of trough section is the best type, as has been proved by experience and careful tests. In consequence, this form of tie is being more and more widely adopted, numerous variations of section and various styles of rail fastenings being used, in accordance with the ideas of different engineers. In England, several railroads are using steel cross-ties to a greater or less extent, but in consequence of the engineers keeping to the double-headed rail in chairs the track is very complicated and expensive, representing money wasted and lying idle in much useless metal, whereas with a good flange rail a metal track might be obtained more economical and more efficient than the present style of rails and chairs on wooden sleepers. Experience has shown that the ends should be closed, but in quite a number of cases open-end ties are used. With open ends, of course, the ties are more liable to lateral displacement, as they do not present the area of resistance presented by a wooden tie or a closed end.

As will be seen by Mr. Post's paper, the Netherland State Railroad Company has made a systematic series of trials of different types of metal ties, and the very valuable and important result of these trials has been the designing of the mild steel rolled tie of trough section, with varying thickness, now well known as the "Post" tie, which has been adopted to a very considerable extent on European lines. Mr. Post has been fortunate in having charge of a road owned by a progressive and far-seeing corporation, which has grasped the economic purposes of metal track, and encouraged its engineer in his work of investigation. The comparisons of the different systems were gone into most thoroughly, account being taken of the amount of labor, time and expense involved in maintenance, renewals and repairs, and therefore Mr. Post has been able to gradually but steadily improve the form of tie, until he has arrived at the present form, which is correct in theory and successful in practice; it is easily manufactured, and has proved in service its advantages in point of economy and efficiency. The trouble experienced with early forms of ties was that they failed by cracking, generally between the holes for rail attachments, and if made thick enough to prevent cracking they were too heavy and expensive. With the "Post" the thickness is increased at the rail seat, giving ample strength where required, but without any undue excess of weight. This strengthening is secured in the operation of rolling by the use of special machinery, and in the same operation is secured the inclination of the ends which gives the rails an inward cant of one in twenty, in accordance with European practice. Many European steel works have orders on hand for "Post" ties.

The question of rail fastenings is one almost as important as that of the type of tie, and many different plans have been tried, some simple, but the majority very complicated. All riveting causes an extra expense, but a very favorite plan is to have a "clamp" or "crab" riveted to the tie to hold one side of the rail flange, the other side being held by a bolted clamp. Mr. Post, realizing that all extra shop work is necessarily expensive, has adopted bolts exclusively, with entirely satisfactory results. It will be noted that the first type of metal tie experimented with had wooden blocks for the rails to rest upon, the idea being that the rail required an elastic seat. This seriously impaired the general efficiency of the tie, for the wood rotted and gave constant trouble, so that this form of tie was soon abandoned. It has been conclusively proved by experience with various types of ties in different countries, that such a wood-bearing is not only unnecessary, but a positive disadvantage, and that the track is satisfactory to railroad men and travelers when the rail is fastened directly on the metal tie, and therefore no wood should be used at all, but a metal track should be entirely of metal. The introduction of metal ties has been hampered by the attempt to secure a "cheap" tie. The objects in using metal are to obtain economy in maintenance and efficiency in operation, and neither of these objects can be obtained by using a tie which is "cheap." Every desirable feature cannot be combined in one piece of steel, and if the tie is to make the track safer, reduce the maintenance expenses, keep the road in better condition, and far outlast the wooden tie, it must have sufficient metal to insure these advantages. You need to have, and to pay for, enough metal to make an efficient tie; but you need not have, and need not pay for extra metal that is mere dead weight. With ties, as with rails, the design and manufacture are equally as important points as the weights, and the rail fastenings no less important.

Two points need to be considered in designing or adopting a metal track, viz.: Economy and simplicity. Cheapness is very far from being economy, being in fact directly opposed to it. Simplicity is necessary, both for economy and efficiency, as the track which, while possessing ample strength, is the most simple in its construction, will give the least trouble, and consequently involve the least expense for maintenance. A good metal track, once well laid, is in itself a source of economy in maintenance and operation, and it is to be hoped that this type of track will soon be a feature of first-class American railroads.

In nearly every large country but America, and in many of the smaller countries, metal ties have been experimented with, and I would strongly urge that more practical attention should be paid to so important a matter by American engineers, railroad men, and steel manufacturers.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

390.

(Vol. XVIII.—June, 1888.)

REPORT OF THE COMMITTEE ON THE COMPRESSIVE STRENGTH OF CEMENTS AND THE COMPRESSION OF MORTARS AND SETTLEMENT OF MASONRY.

READ AT THE ANNUAL CONVENTION OF 1888.*

In the report made in July last, mention was made of the Watertown experiments,† but the results were but partly given, and your Committee propose at this time to discuss them as a whole.

The first tests to be noticed are compressive tests of three kinds of bricks, viz.:

First.—Hard-burned face bricks from North Cambridge, Mass. The average pressure at which flaking-off occurred in three specimens was 7 100 pounds per square inch.

The specimens crushed at an average of 13 925 pounds per square inch.

Second.—Three hard-burned common bricks from the same place

* Committee—Messrs. F. Collingwood, D. J. Whittemore, W. W. Maclay, T. C. McCollom, George F. Swain and A. V. Abbott.

The substance of this report was given verbally by the Chairman at the Annual Meeting, January, 1888. It was completed, and with the diagrams presented at the Convention.

† See "Report of the Chief of Ordnance for 1884," Senate Doc. No. 35, First Session, 49th Congress.

flaked at an average pressure of 8 800 pounds per square inch, and crushed at an average pressure of 18 337 pounds per square inch.

Third.—Three "Bay State" medium bricks from Cambridge and Boston flaked at an average of 6 620 pounds, and crushed at an average of 11 406 pounds per square inch.

Flaking occurred with many specimens at about 5 000 pounds.

Passing to cement tests, we must express our regret that the tests were not made with more definiteness of plan, as it is impracticable to institute comparisons. Those on neat Dyckerhoff Portland cement are quite full at twenty-two months' age, in the form of neat cement. This gives high results, but not so valuable as if made on mixtures ordinarily used.

Again, the Norton cement is tested at forty-six months, mixed 1½ and 3 parts sand to 1 cement.

The Newark and Rosendale was tested at twenty-seven months' age, mixed 1 to 3 (but five cubes, so far as this investigation is concerned, being of use). It was also tested slightly in concrete.

The packings used in testing were variable. Experiments showed a loss of strength of about 25 per cent. at rupture, when the specimens were packed with wood, as compared with those where brass strips or plaster of Paris were used; and the latter gave the most uniform results of all.

The National Portland was quite fully tested in cubes forty-six months old, mixed 1 cement to 3 sand.

Six cubes of each dimension, from 1 to 12 inches, of Dyckerhoff Portland were tested. They were molded in pine boxes on a blue-stone flag, and were tamped with a piece of hard wood as a rammer, struck by a four-pound hammer.

On the contrary, the large cubes of the other cements were rammed with an iron rammer 2 feet long and 1 inch diameter, with a conical point.

Table No. 1 and the curves on Plate No. LXVIII give the average results from the Dyckerhoff Portland for the 8 to 12-inch cubes (there being five of the 8-inch and six of each of the others), and also for three 12-inch piers respectively: No. 79½, 12 inches; No. 77½, 18 inches; and No. 78½, 24 inches high, built each of three prisms.

By reference to the individual tests it will be seen that the blocks giving the greatest strength at rupture do not always give the least compressions. The three piers give about the same strengths. The 11

and 12-inch cubes were packed with plaster, and the other cubes, etc., with brass strips.

The 6-inch Portland cubes, of which curves are shown, were from an unknown brand, and were also packed with brass strips. The error arising from this cause is very plainly shown by the curve.

It will be noted that the 11 and 12-inch cubes gave from one-third to one-half less compression than the smaller ones, showing the superiority of the plaster packing.

The other cement and concrete tests were with plaster of Paris beds.

The concrete cubes of the Newark and Rosendale cements gave 21 per cent. greater strength than the mortar cubes of the same age; but the tests of Rosendale are too few for exact comparison.

The cubes failed generally, by splitting off at the sides (see figure, page 202), the remaining portions forming two truncated pyramids, the smaller ends facing, and their bases formed by the two bed surfaces. There was occasionally a tendency to develop pyramids with the apexes overlapping.

Prisms failed in a similar manner.

Before final fracture occurred, snapping sounds were heard, and cracks were exposed to view on the sides of the specimens.

The average resistances of different cubes and prisms were as follows:

Cubes.		Prisms.	
Nominal dimensions.	Average resistance per square inch.	Nominal dimensions.	Average resistance per square inch.
	Pounds.	Inches.	Pounds.
1-inch cubes.	5 895	4 x 4 x 1	16 460
2 " "	7 053	4 x 4 x 2	6 370
3 " "	5 892	4 x 4 x 3	6 005
4 " "	4 859		
5 " "	4 611	8 x 8 x 2	9 885 (Including broken specimen.)
6 " "	4 272	8 x 8 x 2	10 664 (Excluding same.)
7 " "	4 987		
8 " "	4 865	8 x 8 x 3	6 168
9 " "	4 745	8 x 8 x 4	5 952
10 " "	4 761	8 x 8 x 5	6 020
11 " "	5 381	8 x 8 x 6	5 771
12 " "	5 435		

The 2-inch cubes were strongest, and the strength decreased to the 6-inch, then rose irregularly to the 12-inch. Two of the latter were not

fractured at 800 000 pounds, above which it was not considered prudent to try the machine.

Of the prisms, the shorter in each case shows the greater strength. Three 12 x 12 x 2-inch prisms used as a pier and supporting the pressure through a 10-inch cube of freestone failed at 6 566 pounds per square inch. Cracking sounds were heard at 5 522 pounds.* A 12 x 12 x 4-inch failed at 4 585 pounds; a 12 x 12 x 6-inch at 4 821 pounds, and 12 x 12 x 8-inch at 4 496 pounds.

Of mixtures of Norton's cement, the author states that cubes mixed of 1 cement to 1½ sand, gave 81 per cent. higher average results than of 1 cement to 3 sand. The average compressive strength for the first was 1 545 pounds per square inch, being 2 050 for 4-inch to 1 250 for 16-inch; and for the second 854 pounds, being 1 324 for 4-inch to 768 pounds for 16-inch.

For concrete cubes, made of 1 part Norton's cement, 1½ sand, and 6 broken stone, the average strength was 1 545 pounds, varying as before from 2 320 to 1 440 for 4 to 16-inch cubes.

For concrete of 1–3 and 6, the average was 1 021 pounds, varying from 1 635 for the smaller to 843 for the 16 inches; the first mixture being about 50 per cent. stronger than the second. Singularly, the mortar and concrete of the first mixture give the same strength while the concrete is in the second mixture, 19.6 per cent. stronger than the mortar.

An interesting experiment, as showing the elasticity of the material, was made with a 12-inch cube of National Portland cement mixed 1 to 3.

The load was run up gradually to 800 000 pounds with but slight injury, and then released, the compression being .0530 inches.

A second application of same load increased the compression 13 per cent., or to .0600; being again released, a third application increased it 12 per cent. more, or to .0665, and after sustaining the load ten minutes this had increased 16 per cent. more, or to .0752, a total increase of 42 per cent. The permanent set was at release .0415, diminishing in six minutes to .0405. A fourth application gave a compression of .0810, increasing in ten minutes to .0930. On release the set diminished at once to .0550, and later to .0532, the same as at the first release. A final ap-

*The author reckons this on the basis of the area of the freestone prism. If the area of the cement prisms be used, the figures would be about two-thirds as much. The lines of rupture would indicate a *mean* as the correct method.

plication of the load gave a compression of .1020 inches, increasing in two minutes to .1210, when the cube went to pieces; the whole experiment occupying one hour and twenty minutes.

The effect of adding lime to Portland cement mortar is in every case to diminish its strength; its action in this respect is stated to be "much more serious with Portland than with Rosendale, weakening both to such an extent that practically there is little difference in the resulting mortars, either as regards strength or compressibility."

The Rosendale cement used in the tests would seem to have been below the usual standard of excellence.

As to brick tests, the crushing strength of single bricks is largely in excess of that of brick piers.

Single bricks between rigid platforms evidently occupy a more favorable position for strength, than when between other bricks or mortar cushions of less strength.

Failure occurs in detail, first by flaking of the edges and corners, and at last when the final pressure is reached by a general disintegration.

One 6-inch cube of plaster of Paris was tested. It acted much like Portland cement, and gave a co-efficient of compression per 100 pounds of .00043 up to 200 pounds and .00028 from 0 to 800 pounds. Crushing occurred at 1 981 pounds, with a total compression on one foot of .08 inches.

With this general statement of results we pass next to the question, which is the real one for which we are in search, viz.: what is the co-efficient of compression of each material tested?

If we refer to Plate LXVIII, showing the curves resulting from pressures and corresponding compressions of the Dyckerhoff Portland cement mixed neat, at twenty-two months' age, we find that without exception there is a greater compression shown at the beginning than after the pressure has reached about 300 to 400 pounds per square inch.

We find also that after passing this pressure the curves are practically straight and nearly parallel up to 3 000 pounds and over.

Again, the smaller cubes show more initial compression than the larger, and the piers also show more compression than the large cubes.

Now all the cubes from 8 to 10 inches inclusive were either without packing or leveled with brass strips; and we find such notes as these: "brass strips, .02 and .015 inches thick under opposite corners," "compression faces, .005 inch convex," etc. The 11 and 12-inch cubes were

packed with plaster of Paris of total thickness .02 to .06 inches, and the three 12-inch square piers each had two joints in addition.

Bearing in mind these differences, we must conclude that in the case of the smaller cubes and the piers there is a greater proportional loss of motion before the specimens come to full bearing, which introduces an error in the compression curve up to 300 to 400 pounds' pressure, and a constant error through the whole.*

Referring to the curves shown, we find that the average of the twenty-nine cubes and three prisms is practically straight from the 400 pounds' point to the 3 800 pounds' point, and gives a co-efficient for the whole of

$$\frac{.03077'' - .00487''}{(3800 - 400) \times \frac{12}{100}} = .0000635 \text{ per 100 pounds of load.}$$

If we take the curve for the 12-inch cubes we get

$$\frac{.01983'' - .00293''}{(3\,000 - 300) \times \frac{12}{100}} = .0000522 \text{ per 100 pounds of load.}$$

The 8-inch curve in like manner gives

$$\frac{.01920'' - .00360''}{(2\,000 - 300) \times \frac{12}{100}} = .0000764 \text{ per 100 pounds of load.}$$

If we produce the straight lines giving these average co-efficients back to the line of abscissas, we find that the line at the 12-inch curve cuts off .001-inch, and that on the average curve and the 8-inch curve about .002-inch, and it would seem that the method just pursued gives the nearest approximation to the truth obtainable from these tests.

The records show that the upper points taken are well within the points where failure begins to be manifest. In one case only was there any cracking at as low a pressure as 1 600 pounds, the average at which snapping sounds or cracking occurred being 4 600 pounds per inch.

The set in each test was first measured at 700 to 1 500 pounds, and from this pressure up to about two-thirds of that at rupture, the increase in set progressed nearly uniformly with the pressure.

As a conclusion from all these tests we may reasonably conclude that for this brand of cement, mixed neat at twenty-two months old the co-efficient of compression in mass is about 0.100005 per 100 pounds, since the 12-inch cubes approach nearest to a continuous mass.

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* It will be seen that about .005 of an inch is the greatest error implied by this supposition, a loss of motion very easily realized.

We come next to the three 6-inch cubes of Portland at fourteen and one-half months' age (see Plate LXVIII). The same phenomena of an almost absolutely straight curve from 300 to 2 200 pounds is noticeable. Produced back it strikes the line of abscissas at .008-inch. The resulting co-efficient is

$$\frac{.0298 - .0110''}{(2\,200 - 300) \times \frac{12}{1000}} = .000824 \text{ per 100 pounds of load.}$$

In subsequent results we will substitute the letter c for the constant $\frac{12}{1000}$ pounds.

The last experiments on neat cement are those made by the Committee, on cement cylinders 24½ inches long and 4½ inches diameter (see Plate LXVIII and Table No. 2). These comprise two cylinders of neat Portland at twenty-eight days' age, one at six months, and one previously reported at one hundred and four days. Of the first and last of these we find the anomaly, as compared with all the previous results, that the compression is least at the beginning. The same tendency is shown in the concrete cylinders. The cause of this is not apparent, but may be determined by further tests. Taking the twenty-eight day tests, and averaging the curve between 100 and 700 pounds, we get a co-efficient.

$$\frac{.0198 - .0020''}{(700 - 100) \times c} = .0002472 \text{ per 100 pounds.}$$

This three-and-a-half months' test gives us an average from 100 to 1 000 pounds, as follows:

$$\frac{.0294 - .0116''}{(1\,000 - 100) \times c} = .0001648 \text{ per 100 pounds.}$$

This differs from the result as stated in previous report on this specimen, since it throws out the sharp initial compression up to 100 pounds.

The curve for the six months' test is convex throughout, but an average between 400 and 1 680 pounds gives

$$\frac{.0200 - .0032''}{(1\,680 - 400) \times c} = .0001094 \text{ per 100 pounds.}$$

Arranging the results in the order of age, we have as follows:

At 28 days (say one month)		from cylinder	test	a co-efficient of	.0002472
" 3½	months	"	"	"	.0001648
" 6	"	"	"	"	.0001094
" 14½	"	"	6-inch cubes,	"	.0000826
" 22	"	"	12 "	"	.0000522
" "	"		8 "	"	.0000764
" "	"		Av. of 29 cubes and 3 piers		.0000635

If the ages be plotted as abscissas and co-efficients as ordinates, it is evident that the curve thus formed would become parallel to the axis of abscissas after a sufficient time.

The twenty-two months cubes were from a different brand of cement from the others, and the result may be affected in a measure.

We pass next to cubes of National Portland cement mixed one cement to 3 sand, and forty-six months old (see Table No. 3, Plate LXIX). Of these two each were tested of 8 × 12 and 16-inch dimensions, giving co-efficients as follows:

The average of the 8-inch gives between 300 and 1 400 pounds for 12 inches length.

$$\frac{.0163 - .0062''}{(1\,400 - 300) \times c} = .0000765$$

The 12 inch give $\frac{.0094 - .0023''}{(1\,300 - 300) \times c} = .0000592$

" 16 " $\frac{.0071 - .0018''}{(1\,200 - 300) \times c} = .0000491$

The average of all is $\frac{.0101 - .0034''}{(1\,200 - 300) \times c} = .0000620$

We have next some tests on National Portland cement concrete, forty-six months old, mixed, one cement, 3 sand and six broken stone (see Table No. 3, and Plate LXIX). These give co-efficients as follows:

Two 8-inch cubes give approximately $\frac{.0178 - .0040''}{(1\,500 - 100) \times c} = .0000821$

Two 12 " " $\frac{.0115 - .0026''}{(1\,200 - 180) \times c} = .0000727$

Two 16 " " $\frac{.0085 - .0010''}{(1\,300 - 100) \times c} = .0000521$

The average of all gives approximately $\frac{.0123 - .0022''}{(1\,300 - 100) \times c} = .0000701$

The interesting result appears that 16-inch cubes of forty-six months' concrete give equal compression with 12-inch cubes twenty-two months old, mixed neat; also the 12-inch concrete corresponds with the 8-inch cement.

The average strength of the neat cement cubes was 2 411 pounds per inch; and of the concrete, 2 899 pounds.

The Committee would, in this connection, present some tests made by them on cylinders 24½ inches long by 4½ inches diameter (see Plate LXVIII, Table No. 2). The specimens consisted of one cylinder, twenty-

eight days old, mixed, 1 of Portland cement to 2 of sand; two of the same age, mixed, 1 to 3, and one six months old, mixed, 1 to 3.

The co-efficients obtained are as follows:

1 cement, 2 sand, twenty-eight days, $\frac{.0187 - .0031''}{(400 - 100) \times c} = .000433$

1 " 3 " " $\frac{.0282 - .0057''}{(400 - 100) \times c} = .000625$

" " 3 " six months, $\frac{.0139 - .0026''}{(500 - 100) \times c} = .000235$

It will be seen that these results are about two and one-half times those reached with the neat cement cylinders in corresponding times, showing that where it is important to have the least possible compression in work, the use of neat cement is indicated.

We have next to examine some tests of Rosendale (natural) cements. These are too few in number to base any positive deductions upon (indeed, this is true in a measure of all the results given), but the Committee hope to supplement them in the future.

We have first, two cubes each 8 inches, 12 inches and 16 inches of Rosendale cement mortar mixed 1 cement, $1\frac{1}{2}$ sand at forty-six months' age (see Plate LXIX, Table No. 4).

The average of the 8-inch gives $\frac{.0163 - .0030''}{(900 - 200) \times c} = .0001584$ per 100 lbs.

" " 12 " $\frac{.0132 - .0049''}{(700 - 200) \times c} = .0001383$ "

" " 16 " $\frac{.0139 - .0041''}{(800 - 200) \times c} = .0001361$ "

" " 6 cubes gives $\frac{.0127 - .0040''}{(700 - 175) \times c} = .0001381$ "

To avoid confusing the diagram the average lines in some cases are omitted.

Six cubes of corresponding sizes at 46 months' age, mixed 1 to 3, give:

The average of the 8-inch gives $\frac{.0167 - .0051''}{(500 - 100) \times c} = .0002417$ per 100 lbs.

" " 12 " $\frac{.0083 - .0019''}{(400 - 100) \times c} = .0001777$ "

" " 16 " $\frac{.0098 - .0027''}{(400 - 100) \times c} = .0001972$ "

" " 6 cubes gives $\frac{.0108 - .0032''}{(400 - 100) \times c} = .0002111$ "

Comparing these results with the National Portland of same age and mixture we find them to be about four times as much.

The average strength at crushing of the 1 to 1½ mixture was 1 386 pounds, and of the 1 to 3 mixture 714 pounds per square inch; and the compression of the latter was about one and one half times that of the former.

Six cubes of Rosendale cement concrete at forty-six months' age mixed 1 cement, 1½ sand and 6 broken stone, gave (see Table No. 5, Plate LXIX).

The average of 8-inch gives $\frac{.0249 - .0058''}{(800 - 100) \times c} = .0002274.$

" 12 " $\frac{.0170 - .0021''}{(800 - 100) \times c} = .0001774.$

" 16 " $\frac{.0098 - .0023''}{(700 - 100) \times c} = .0001042.$

Average of all..... $\frac{.0170 - .0034''}{(770 - 100) \times c} = .0001692.$

Six cubes concrete of a mixture of 1 Rosendale to 3 sand and 6 broken stone at forty-six months' age, gave:

For 8-inch gives $\frac{.0261 - .0075''}{(600 - 100) \times c} = .0003100$ per 100 pounds.

12 " $\frac{.0102 - .0018''}{(500 - 100) \times c} = .0001750$ " "

16 " $\frac{.0100 - .0022''}{(500 - 100) \times c} = .0001625$ " "

Average of all.. $\frac{.0139 - .0038''}{(500 - 100) \times c} = .0002104$ " "

The crushing strength of the concrete with 1½ parts sand was 1 483 pounds, and with three parts sand 824 pounds average per square inch. The crushing strength of the 1 to 3 to 6 mixture with National Portland cement was 2 899 pounds, or three times that of the Rosendale, while the compressions were from about one-half to one-quarter.

Another brand of Rosendale cement mixed 1 cement, 2 sand, 3 gravel and 4 broken stone at twenty-two months old gave for 1 cube, each size, as follows:

10-inch cube	$\frac{.0132 - .0013''}{(600 - 100) \times c}$	$= .0001983$
12 "	$\frac{.0153 - 0026''}{(600 - 100) \times c}$	$= .0002117$
16 "	$\frac{.0089 - 0022''}{(500 - 200) \times c}$	$= .0001861$
18 "	$\frac{.0119 - 0022''}{(600 - 100) \times c}$	$= .0001617$
Average of all	$\frac{.0104 - 0021''}{(500 - 100) \times c}$	$= .0001729$

It will be noted that in all cases the averages have been taken from the average curves, rather than by averaging the co-efficients, although they do not differ greatly.

Two cylinders $24\frac{1}{2}$ x $4\frac{1}{8}$ inches of a mixture of 1 part lime, 2 parts pozzuolana, and 3 parts quartz by weight (or 1 each by volume) were tested as follows, giving the following results on 12-inch length:

No. of Test.	Age.	Pressure per inch in pounds.						Ultimate strength per square inch. Pounds.
		100	200	300	400	500	600	
20	3 mos.	.0090	.0170	.0240	.0254	....	....	524
21	6 "	.0049	.0123	.0232	....	....	....	449
22	6 "	.0029	.0053	.0084	.0138	.0204	.0340	749

Brick Piers.

One of the most important series of tests in the Watertown record is that of thirty-three brick piers of various dimensions and lengths. The bricks were laid on the bed, with joints broken in every course, excepting in two cases. Their ages ranged from fourteen to twenty-four months. Compression measurements were taken within the gauged length along the center line. Contact of the pier with the beam of the micrometer was made through blocks carrying conical spur points clamped to the bricks. If these measurements could have been made on opposite sides, so as to throw out all effect of flexure, if any, it would possibly have given more uniformity in results.

The piers seem to have been packed with brass strips against steel cushions, in testing.

Loads were applied in regular increments, measuring the compression at each, and returning to zero occasionally to determine the set.

Cracks made their appearance at the surfaces of the piers, and were gradually enlarged before maximum loads were reached. Final failure

occurred by partial crushing of some bricks, and enlargement of the cracks. These took a longitudinal direction, and occurred in the bricks of one course opposite the end joints of adjacent courses.

Snapping sounds were heard long before cracks appeared; in one case at 200 pounds, another at 300, in about three at 400, and four at 500 pounds per square inch. In one case it ran to 1 800 pounds, and in a large number at 1 100 to 1 500, the average being about 900 pounds.

Piers laid in Portland cement showed the highest resistance, showing that the quality of the mortar has much to do with the strength of brick work.

The experiments seem to show that, when lime mortar is used, the yielding was much of it in the joints. In one respect the curves shown, Plates LXX and LXXI are misleading, for the following reason: the piers were transported to the testing machine in a fixture consisting of two cast-iron plates, which were set on the ends of the piers in plaster of Paris. These were joined by wrought-iron tie rods provided with turn-buckles, by tightening which the inclosed pier was placed in a state of compression. This compression was often greater than the initial loads applied, so that the early readings are not strictly correct. This result is most conspicuous in the piers laid in weak mortars.

The second application of a given load (after release from the first application), usually caused an increase in the total compression, although not always. The opinion is expressed that repeated loading would ultimately destroy a pier; but as this increased compression sometimes occurs with loads as low as 150 pounds per inch with cement mortar, the theory is questionable. The remarkable fact comes out by one of the experiments that under application of a lighter load after a heavier one, the set perceptibly diminishes, and this occurs even quite near the load causing rupture.

For example, a pier 12 inches square, 73 inches high, gauged length 50 inches, gave at 139 pounds per square inch a total compression of 0.0103 inches, increasing in five minutes to .0109 inches. On release to 70 pounds, the set measured .0065. At 348 pounds the compression was .0504, increasing as before to .0527. On release to 70 pounds, the set was .0328, diminishing to .0327 in five minutes.

Again, at 556 pounds, the compression was .0955, increasing to .0994. On release, as before, the set was .0653, after five minutes, .0649, and after sixty-five minutes .0646. At 694 pounds, the first crack appeared,

and compression after five minutes was .1334, diminishing on release to 70 pounds to .0908, and after five minutes to .0902. At 900 pounds the figures were (in the same sequence) .1872, .1908, .1345 and .1377 inches, respectively. Total failure occurred at 1 210 pounds per inch.

Piers in lime mortar, with joints broken every sixth course, seemed to be stronger than with joints broken every course; but more experiments are required to substantiate the statement.

Hollow piers were, for the same mortars, of about the same strength as solid, per square inch of solid section.

A terra-cotta cylinder, made up of three segments, each 5½ inches high, joined with neat cement, gave a co-efficient for 12 inches of about .000102.

A pier 12 inches square, 50 inches high, within gauge marks, laid up in Portland cement, neat, at nineteen and one-half months' age, gave (see Table No. 6, Plate LXX.)

$$\frac{.0100 - .0003''}{(1300 - 200) \times c.} = .0000735$$

One pier, 8 inches square, 16¼ inches high and fifteen months old, of face-brick, set in Portland cement mortar, mixed 1 to 2, gives a remarkably uniform curve and a co-efficient of

$$\frac{.0281 - .0064''}{(1500 - 400) \times c.} = 0.0001644$$

One pier, 12 inches square, 23½ inches high, of face-brick, eighteen-and-a-half-months-old-Portland mortar, 1 to 2, gave, up to 1 400 pounds, a co-efficient of..... .0001597

One pier, 16 inches square, 32 inches high, of common brick, same age, etc., up to 700 pounds, gave same..... .0001597

Beyond 700 pounds the common brick compressed the most.

Four piers, twenty-three to twenty-four months old, 8 to 16 inches square, 50 to 100 inches high (see Table No. 6), gave, with Portland mortar, 1 to 2, as follows:

Between limits of 200 and 1400 pounds—

No. 328, of common brick, 16 inches square, 100 inches gauged height, co-efficient.....	.0000667
" 329, of common brick, 12 inches square, 100 inches gauged height, co-efficient.....	.0000658
" 326, of face brick, 12 inches square, 100 inches gauged height, co-efficient.....	.0000722
" 321, of face brick, 8 inches square, 50 inches gauged height, co-efficient.....	.0000652

Finally, there were four tests in every particular alike except the mortar.

They were of Bay State bricks, twenty to twenty and one-half months old, height 50 inches. The strongest and the one showing least compression was laid up in Rosendale cement mortar, mixed 1 to 2, and gave a co-efficient, between 300 and 1 000 pounds, of..... .0001012

The next, with Portland cement, 1 to 2, between 400 and 1 000, gave..... .0001083

Rosendale, mixed 1 to 2 sand and 6 lime, between 300 and 800, gave..... .0001800

Portland, 1, 2 and 6, gave between 300 and 900..... .0001639

Collecting the results, we find:

	Co-efficient, per 100 pounds.	
One pier, 19½ months, Portland mortar neat, Bay State bricks	.0000735	
One pier, 15 months, Portland, 1 to 2 face, Bay State bricks	.0001644	
One pier, 18½ months, Portland, 1 to 2 each face and common, about	.0001597	up to 700
One pier, 20 months, Rosendale, 1 to 2 Bay State	.0001012	
One pier, 20 " Portland, " "	.0001083	
One pier, 20½ months, Portland, 1 cement, 2 lime, 6 sand, Bay State	.0001639	
One pier, 20½ months, Rosendale, 1 cement, 2 lime, 6 sand Bay State	.0001800	
One pier, 24 months, Portland, 1 cement 2 sand, common	.0000667	
One pier, 24 months, Portland, 1 cement 2 sand, common	.0000658	
One pier, 23½ months, Portland, 1 cement 2 sand, face	.0000722	
One pier, 23½ months, Portland, 1 cement 2 sand, face	.0000652	

For a refined comparison a much greater number of experiments is requisite. It is evident that there is an increased resistance to compression with increase of age, but it is quite evident also that the figures given are too irregular to be exact.

The only way to make exact determinations will be to build the piers with exactly the same dimensions and thickness of joints and of the same quality of bricks for each mixture of mortar. It is inevitable that as walls are ordinarily built with more or less voids, the compressions must exceed those given in every case.

Brick Piers in Lime Mortar.

One of the first things to be observed in this Table No. 7 (Plate LXXI) is the very decided loss of strength at rupture of the piers built of Bay State bricks, as compared with the relative strengths in the previous table. This shows very forcibly the important part played by the mortar in any structure.

Taking the piers in the order of age, we have:

1st, two 8-inch piers, 16 inches high, fifteen months old, of which the face brick gives co-efficient..... .0004157
The common brick gives co-efficient..... .0005903
And the average..... .0005048

At eighteen and one-half months the piers are 23 to 24 inches high and 12 inches square.

The face brick gives... .0003208 and .0004312 or an average of .0003760
The common brick gives..... .0007708 and .0005555 " " .0006631
One of the Bay State bricks gives..... .0005950
Average of all at eighteen and one-half months..... .0005260

At nineteen and one-half to twenty months these piers of Bay State bricks, 12 inches square and 72 inches high, give respectively:
.0004417 .0004222 .0002858 and average .0003832

At twenty-three to twenty-four months there are nine piers from 80 to 121 inches high. Of these the face brick give:
.0003131 .0003521 .0002933 and average .0003195

The common brick give:
.0005333 .0008000 and average .0006667

The Bay State brick give:
.0003983 .0005306 .0007500 .0006389 and average .0005794

In every case it will be seen that with lime mortar the face bricks give the least compression, the Bay State appears to be next, and the common brick most. With cement mortar, so far as the experiments go, there is little difference. Referring to thickness of the joints we see those with face bricks are thinnest; and this, together with the greater compression in cubes of lime mortar, would indicate that the increased compression with common bricks occurs largely in the joints, and that the kind of brick has little to do with it. The form of pier, whether hollow or solid, seems to have little effect also.

Brick Piers with Stone Caps and Bases.

In connection with the foregoing were six piers of North River hard-burned brick, with caps of Kanawha freestone from Virginia. Three 2-inch cubes of the freestone crushed at an average strength of 9 154

pounds per square inch. The piers were laid up with Newark and Rosendale cement, mixed 1 to 2, and were twenty-two months old. The height of the brick work was 16 to 16½ inches, and total height of piers 22 to 22½ inches, the compressions being measured on the whole height.

The curve of the average compressions only has been plotted in Plate LXXII, Table No. 8. Taking the range between 100 and 900 pounds per square inch, gives a co-efficient of .0001469 per 100 pounds.

Haverstraw Freestone Cubes.

A series of these were tested, giving compressive strength as follows:

Size.	Number of cubes.	Minimum strength per square inch.	Maximum strength per square inch.	Average strength per square inch.	Size.	Number of cubes.	Minimum strength per square inch.	Average strength per square inch.	Maximum strength per square inch.
Inches.		Pounds.	Pounds.	Pounds.	Inches		Pounds.	Pounds.	Pounds.
1	2	6 959	7 107	7 033	7	4	5 728	6 590	6 156
2	4	5 590	6 718	6 004	8	4	6 040	6 674	6 272
3	4	5 795	7 202	6 245	9	4	5 494	7 886	6 535
4	4	5 340	6 341	5 962	10	4	5 210	8 032	6 584
5	4	5 302	8 052	6 467	11	4	6 270	6 508	6 418
6	4	7 048	7 719	7 355	12	4	5 323	5 621	5 420

It should be said that one of the 10-inch cubes cracked, but did not rupture entirely. Three of the 12-inch cubes also did not rupture, as the limit of strength of the machine was reached. Nevertheless, the averages do not indicate the increase with increase of dimension that has been held to be the law by previous observers.

Prisms of the same stone, two of each size, were tested as follows:

Size.	Minimum per square inch.	Maximum per square inch.	Average per square inch.
4 x 4 x 1 inch.	14 070	18 786	16 428
4 x 4 x 2 "	7 835	8 222	8 028
4 x 4 x 3 "	6 141	7 216	6 678
8 x 8 x 2 "	12 300	12 610	These prisms were not ruptured.
8 x 8 x 3 "	8 823	10 251	9 537
8 x 8 x 4 "	7 765	9 336	8 550
8 x 8 x 5 "	6 937	8 590	7 763
8 x 8 x 6 "	6 281	6 788	6 554
8 x 8 x 7 "	6 537	6 689	6 613
From other tables.			
8 x 8 x 8 inch.	6 040	6 674	6 272

The 8 x 8 x 2 inch it is evident would have given at rupture about the same strength as the 4 x 4 x 1 inch. The 8 x 8 x 4 inch were a little stronger than the 4 x 4 x 2 inch; the 8 x 8 x 6 inch a little weaker than the 4 x 4 x 3 inch, and the 8-inch cubes and 4-inch cubes almost identical.

As all these blocks and cubes were carefully selected, so as to be as uniform as possible, the results are certainly interesting.

Compressions were measured on the cubes from 8-inch in size upward, and the curves of the average are plotted on Plate LXXII, Table No. 9. The average of the 20 cubes between 100 and 700 pounds give a co-efficient of

.000175 per 100 pounds.

Beyond this the compression is less, and from about 1 400 to 5 000 pounds it is almost uniform at .0000882.

It will be seen that the first result is very close to the average obtained for cubes of forty-six-months-old Rosendale concrete and mortar. The last is more nearly that of National Portland concrete and mortar.

One reason for the irregular character of the curves for the freestone blocks is that readings were only taken for compression at wide intervals of pressure.

The curve given of the test of a pier of three cubes gives essentially the same result.

In concluding this report of progress we can only say that the results are to be considered as approximations only. The method of averages is undoubtedly the right method to pursue, since every large mass of masonry will present variations throughout its mass, so that the result of pressure on such a mass must be an average between the best and all grades to the poorest.

We hope to be able to obtain more extended tests before making our final report.

TABLE No. 1.

DYCKERHOFF PORTLAND CEMENT (neat.) Specimens twenty-two months old, buried in sand while hardening. The compressions are reduced to the amount for a foot in length of test. The prisms tested were 12 x 12 inches, there being three of 2 inches, three of 4 inches and three of 8 inches, tested in piers 12, 18 and 24 inches high, respectively, with compressions reduced to that on 1 square inch. (The 11 and 12 inches packed with plaster of paris; the others with brass strips when tested.)

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Pressures per square inch per foot of length, lbs.	100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 800	1 900	2 000	2 200	2 400	2 600	2 800	3 000	3 400	3 800	4 400	4 800	5 200	5 600	Rupture. Lbs.
Average compression of five 8-inch cubes.....	.00111	.00216	.00360	.00480	.00603	.00717	.00819	.00933	.01038	.01122	.01197	.01314	.01398	.01467	.01554	.01620	.01701	.01776	.01851	.01920	.02088	.02235	.02352	.02511	.02718	.03003	.03420	.04203	.....	.....	.....	4 781
Average of six 9-inch cubes.....	.00123	276	467	607	740	849	967	1 064	1 164	1 267	1 351	1 438	1 513	1 573	1 684	1 767	1 851	1 940	2 007	2 080	2 220	2 347	2 511	2 640	2 797	3 103	3 489	3 890	.....	.....	.....	4 745
Average of six 10-inch cubes.....	.00112	320	470	620	722	834	924	1 014	1 084	1 170	1 230	1 294	1 374	1 458	1 522	1 594	1 664	1 728	1 768	1 810	1 972	2 084	2 220	2 346	2 484	2 712	2 873	3 192	.....	.....	.....	4 761
Average of six 11-inch cubes.....	.00083	205	308	383	452	527	594	661	725	775	837	903	961	1 021	1 075	1 129	1 220	1 274	1 347	1 413	1 534	1 670	1 796	1 945	2 087	2 397	2 732	3 380	.03698	.04296	.05072	5 381
Average of six 12 inch cubes.....	.00080	187	293	360	430	496	555	610	670	723	783	843	910	980	1 039	1 090	1 153	1 203	1 260	1 340	1 453	1 593	1 716	1 840	1 983	2 285	2 626	3 280	3 810	4 020	4 550	5 439
Average of three piers of three prisms each..	.00110	241	336	453	542	612	683	785	839	911	982	1 061	1 132	1 194	1 265	1 341	1 416	1 504	1 580	1 661	1 837	2 019	2 212	2 424	2 653	3 132	3 658	4 304	5 582	.....	.....	4 635
Average of twenty-nine cubes and three piers.	.00102	241	375	487	585	677	763	847	925	999	1 068	1 146	1 218	1 287	1 358	1 425	1 503	1 572	1 636	1 703	1 845	1 981	2 123	2 274	2 429	2 733	3 077	3 613	4 087	4 158	4 811	4 828

PORTLAND CEMENT NEAT. SPECIMENS 14½ MONTHS OLD.

Average of three 6-inch cubes for 12-in. length.	.0043	.0088	.0110	.0118	.0130	.0140	.0150	.0162	.0170	.0180	.0190	.0200	.0210	.0220	.0230	0.240	.0250	.0262	.0274	.0286	.0298	.0348	.0382	0.418	.0450	

TABLE No. 1 A.

ITCKERHOFF'S PORTLAND CEMENT. Individual tests from which averages in Table No. 1 are computed. The upper line indicates pressures per square inch, and the lines below compressions in inches on the sizes given without reduction to uniform length.

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Thickness of Plaster.	No of Test.	Size.	Pounds.																													Rupture.
			100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 800	1 900	2 000	2 200	2 400	2 600	2 800	3 000	3 400	3 800	4 400	4 800	5 200	5 600	
Inches...		Inches.																															
.....	49	8	".0013	".0026	".0039	".0051	".0062	".0067	".0080	".0092	".0101	".0108	".0110	".0119	".0127	".0131	".0139	".0145	".0105	".0157	".0163	".0170	".0181	".0193	".0200	".0213	".0230	".0255	".0287	".0350	.....	.....	.....	4 629
.....	50	8	8	11	20	24	34	43	50	57	63	68	72	80	87	91	97	101	107	113	120	125	137	147	157	168	183	202	230	296	.....	.....	.....	4 550
.....	51	8	2	8	17	24	27	38	42	50	59	65	70	74	80	84	88	92	98	102	107	110	120	128	135	144	155	174	195	244	260	.....	.....	4 800
.....	52	8	6	14	22	30	38	43	50	57	62	66	70	77	80	88	95	100	105	110	113	115	130	140	150	160	170	192	218	264	.....	.....	.....	4 669
.....	53	8	8	13	22	31	40	48	51	56	61	67	77	88	92	95	99	102	107	110	114	120	128	137	142	152	168	178	210	247	272	....	.....	5 256
.....	54	9	9	23	38	50	62	72	82	92	100	110	114	120	127	133	140	146	151	158	163	170	182	190	200	210	220	240	264	320	.....	.....	.....	4 574
.....	55	9	10	28	45	60	73	84	98	108	118	127	136	114	152	160	168	177	184	189	194	200	211	220	230	240	250	270	293	325	.....	.....	.....	4 538
.....	56	9	10	25	40	52	62	70	79	86	92	100	106	114	121	128	134	140	148	153	159	164	176	187	198	205	218	246	256	.....	.....	.....	.....	4 889
.....	57	9	4	10	15	23	30	34	40	45	52	58	62	68	72	77	82	87	91	101	105	110	120	131	143	153	165	184	214	270	.....	.....	.....	4 783
.....	58	9	15	26	37	44	53	60	67	74	79	85	90	94	97	101	107	112	119	125	130	133	140	152	160	170	179	197	230	252	.....	.....	.....	5 736
.....	59	9	8	12	35	44	53	60	69	74	83	90	100	107	112	119	127	133	140	147	152	159	170	188	199	210	227	259	323	.....	.....	.....	.....	3 949
.....	60	10	15	38	53	70	79	90	101	109	113	119	125	132	140	145	151	158	166	170	177	181	192	201	211	223	236	270	.....	.....	.....	.....	.....	3 902
.....	61	10	3	10	15	21	24	28	34	40	46	51	54	59	64	71	77	81	85	89	93	98	105	115	124	132	144	158	180	217	.....	.....	.....	5 859
.....	62	10	8	42	60	75	87	100	107	115	120	127	130	134	140	148	150	155	160	165	170	175	185	190	200	210	220	240	260	290	.....	.....	.....	5 123
.....	63	10	12	30	46	62	73	84	93	103	112	120	127	132	139	147	150	157	162	168	172	180	193	204	215	225	230	.....	.....	.....	.....	.....	.....	4 225
.....	64	10	8	20	31	42	52	62	68	75	80	90	95	100	108	116	124	130	136	142	147	151	161	174	190	203	219	242	272	.....	.....	.....	.....	4 710
.....	65	10	10	20	30	40	46	53	59	65	71	78	84	90	96	102	109	116	123	130	135	140	150	160	170	180	193	220	245	290	.....	.....	.....	4 747
.....	66	11	7	21	33	40	47	55	62	69	76	82	90	95	100	105	110	119	126	131	138	144	154	167	180	200	212	248	280	348	.....	.....	.....	4 820
.03.....	67	11	10	26	39	44	50	60	67	70	76	80	85	93	100	103	110	117	123	127	130	138	147	160	171	185	200	226	257	320	358	412	.....	5 246
.02.....	68	11	7	17	27	34	40	46	52	59	67	71	77	83	90	97	102	109	113	119	125	130	142	157	169	183	200	230	260	319	356	402	465	5 896
.02.....	69	11	6	10	16	23	30	35	42	49	53	57	62	67	70	77	81	86	95	102	108	115	128	140	150	160	170	195	220	282	313	362	.....	5 451
.03.....	70	11	7	19	25	30	36	41	45	50	55	60	65	70	75	80	85	90	100	105	110	115	128	140	150	162	173	200	230	290	330	390	.....	5 587
.02.....	71	11	9	20	30	40	46	53	59	67	72	77	82	89	94	100	104	109	114	123	130	135	145	158	168	180	193	220	250	300	338	403	.....	5 287
.04.....	72	12	8	16	22	29	36	43	50	56	60	67	69	79	85	92	95	100	107	112	118	127	140	157	170	188	205	235	278	365	460	.....	.....	4 910
.03.....	73	12	13	26	39	46	54	61	68	77	84	90	99	104	110	115	120	128	135	140	144	152	160	178	190	203	220	255	290	360	.....	.....	.....	5 379
.06.....	74	12	8	20	30	38	42	50	58	62	69	73	79	83	90	100	105	110	118	121	128	137	150	160	170	183	194	218	245	298	340	422	.....	5 542
.03.....	75	12	6	14	27	31	38	45	49	54	61	69	75	80	87	94	102	108	111	117	121	129	140	152	162	172	185	213	246	299	350	390	455	5 900
.07.....	76	12	6	17	28	32	40	47	50	55	60	62	68	72	79	86	90	98	102	108	115	120	134	147	160	173	187	214	246	311	355	395	.....	5 533
.01.....	77	12	7	20	30	39	48	52	58	62	68	73	80	88	94	101	107	111	119	124	131	138	148	162	178	186	199	236	271	337	400	.....	.....	5 343
Beams.	79½	12 x 12 totals.	8	20	32	41	54	63	72	80	89	98	105	114	122	130	139	148	158	170	180	190	211	232	254	276	300	354	410	.....	.....	.....	.....	4 588
	77½	.....	22	41	59	72	82	91	102	117	127	136	149	160	160	178	189	199	209	220	231	244	270	299	332	370	410	490	579	730	840	.....	.....	4 821
	78½	.....	21	50	77	94	108	120	130	145	156	169	180	195	210	219	231	243	255	269	280	291	320	349	378	409	445	518	603	765	.....	.....	.....	4 496

TABLE No. 2.

PORTLAND CEMENT, mixed neat, in cylinders $4\frac{1}{8}$ inches diameter, $24\frac{1}{2}$ inches long. Section, $13\frac{3}{100}$ square inches. Compression in inches for 12 inches in length.

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(1)—Specimen twenty-eight days old.

Description, etc.	Pressures in Pounds per Square Inch.																														Rupture.
	100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 800	1 900	2 000	2 100	2 200	2 300	2 400	2 500	2 600	2 700	2 800	2 900	3 000	
Specimen No. 4	.0020	.0047	.0081	.0111	.0142	.0160	.0184	.0207	.0221	.0247	.0268	.0290	.0305	.0325	.0352	.0380	.0403	.0417	.0444	.0466	.0489	.0506	.0540	.....	.....	.....	.....	.....	.....	.....	3 270 pounds.
" 3	.0020	.0045	.0078	.0112	.0143	.0178	.0211	.0227	.0253	.0270	.0289	.0302	.0319	.0335	.0363	.0374	.0387	.0406	.0434	.0451	.0469	.0488	.....	.....	.....	.....	.....	.....	.....	.....	3 000 "
Average	.0020	.0046	.0079	.0112	.0143	.0169	.0198	.0217	.0237	.0259	.0279	.0296	.0312	.0330	.0358	.0377	.0395	.0412	.0439	.0459	.0479	.0497	.0540	.....	.....	.....	.....	.....	.....	.....	3 135 "

(2)—Specimen one hundred and four days old.

One specimen reported July 4, 1887	.0116	.0131	.0147	.0172	.0193	.0217	.0239	.0259	.0279	.0294	.0309	.0319	.0342	.0361	.0372	.0331	.0389	.0412	.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

(3)—Specimen six months old.

Specimen No. 5	.0006	.0013	.0020	.0032	.0045	.0059	.0068	.0076	.0086	.0101	.0111	.0129	.0143	.0158	.0176	.0187	.0203	.0231	.0248	.0257	.0275	.0294	.0307	.0321	.0353	.0379	.0394	.0426	.0454	.0462	3 598 pounds.

(4)—Specimen (1 Portland and 2 sand) twenty-eight days old.

Specimen No. 12	.0031	.0061	.0135	.0187	.0232	.0244	.0314	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 050 pounds

(5)—Specimen (1 Portland and 3 sand) twenty-eight days old.

Specimen No. 15	.0057	.0125	.0.06	.0286	0.360	.0479	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	600 pounds.
Specimen No. 16	.0057	.0117	.0196	.0278	.0354	.0479	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	600 "
Average	.0057	.0121	.0201	.0282	.0357	.0479	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	600 "

(6)—Specimen (1 Portland and 3 sand) six months old.

Specimen No. 17	.0026	.0056	.0083	.0114	.0139	.0154	.0180	.0210	.0237	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 050 pounds.

TABLE No. 2 A.

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WHICH HAS NOT BEEN REDUCED TO 100 POUNDS PRESSURE PER SQUARE INCH.

No. 6. Neat Portland cement cylinder, one year old. Length, 24.030 inches. Area, $13\frac{36}{100}$ square inches.

Load. Pounds.	Compression. Inches.	Load. Pounds.	Compression. Inches.	Load. Pounds.	Compression. Inches.
2 000	0.0064	12 000	.0510	22 000	.0775
3 000	.0170	13 000	.0530	23 000	.0800
4 000	.0212	14 000	.0580	24 000	.0822
5 000	.0265	15 000	.0605	25 000	.0840
6 000	.0320	16 000	.0635	26 000	.0875
7 000	.0355	17 000	.0650	27 000	.0895
8 000	.0395	18 000	.0685	28 000	.0935
9 000	.0435	19 000	.0710	29 000	.0940
10 000	.0475	20 000	.0735	30 000	.0950
11 000	.0000	21 000	.0750	31 000	.0990
				32 000	.1005

Crushed at 53 550 pounds.

No. 14. 1 Portland cement, 2 parts sand, one year one day old. Length, 24.500 inches. Area, $13\frac{36}{100}$ square inches.

Load. Pounds.	Compression. Inches.	Load. Pounds.	Compression. Inches.
2 000	.0025	11 000	.0255
3 000	.0055	12 000	.0285
4 000	.0110	13 000	.0325
5 000	.0135	14 000	.0340
6 000	.0150	15 000	.0365
7 000	.0160	16 000	.0395
8 000	.0175	17 000	.0425
9 000	.0195	18 000	.0500
10 000	.1225	19 000	.0620 crushed.

No. 19. 1 Portland cement, 3 parts sand, one year sixteen days old. Length, 24.500 inches. Area, $13\frac{36}{100}$ square inches.

Load. Pounds.	Compression. Inches.	Load. Pounds.	Compression. Inches.
2 000	.0110	8 000	.0440
3 000	.0175	9 000	.0480
4 000	.0230	10 000	.0545
5 000	.0290	11 000	.0595
6 000	.0340	12 000	.0665
7 000	.0380	13 000	.0780
		14 000	crushed.

Vol

No. o
Test

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161
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TABLE No. 3.

Mortar Cubes of National Portland Cement (1 cement and 3 sand), forty-six months old. Tested between steel faces packed with plaster of paris.

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No. of Tests.	Kind.	Pressures per Square Inch in Pounds.																								Ultimate Pounds.	Area. Square Inches.
		100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1500	1 600	1 700	1 800	1 900	2 000	2 200	2 400	2 600	2 800	3 000		
	Inches.																										
160	8	.0008	.0014	.0020	.0026	.0032	38	43	49	54	59	64	69	74	80	87	94	102	108	115	122	140	161	.....	.....	.....	.....	2 586	64.96
161	8	.0033	51	63	70	77	85	93	100	106	113	120	126	132	139	146	153	162	171	180	194	218	.....	.....	.....	.....	.....	2 370	63.28
Average compression on 12 inches		.0030	.0048	.0062	.0072	.0031	.0092	.0102	.0111	.0120	.0128	.0138	.0146	.0154	.0163	.0174	.0185	.0198	.0209	.0221	.0237	.0269	.....	.....	.....	.....	.....	2 478	64.12
162	12	.0012	18	25	38	45	51	58	67	72	77	82	87	95	103	113	120	129	140	152	167	198	.....	.....	.....	.....	.....	2 472	144.60
163	12	.0005	14	21	28	34	40	45	54	62	70	77	85	93	104	117	125	135	149	162	178	217	290	.....	.....	.....	.....	2 396	144.24
Average		.0009	.0016	.0023	.0033	.0040	.0046	.0052	.0060	.0067	.0074	.0080	.0086	.0094	.0104	.0115	.0123	.0132	.0145	.0157	.0173	.0208	.....	.....	.....	.....	.....	2 434	144.42
164	16	.0004	11	19	27	34	41	48	56	63	70	76	86	95	103	114	124	133	144	157	172	196	246	.....	.....	.....	.....	2 501	259.85
165	16	.0007	18	29	35	42	48	58	67	77	86	95	103	114	125	136	148	161	173	184	203	234	284	.....	.....	.....	.....	2 538	257.92
Average compression on 12 inches		.0005	.0011	.0018	.0023	.0029	.0034	.0040	.0047	.0053	.0059	.0065	.0071	.0079	.0086	.0094	.0102	.0110	.0119	.0128	.0141	.0161	.0199	.....	.....	.....	.....	2 520	258.88
Total average compression on 6 cubes		.0015	26	34	42	50	57	64	72	80	87	94	101	109	118	127	136	146	158	169	186	213	244	.....	.....	.....	.....	2 411	.....

Concrete Cubes of National Portland Cement (1 cement, 3 sand and 6 broken stone), forty-six months old.

170	8	.0041	48	56	62	66	69	75	81	84	89	95	100	105	110	116	123	132	140	148	158	177	205	246	300	405	3 059	64 24
171	8	.0013	24	32	38	44	51	58	64	71	77	84	92	101	111	121	133	146	162	179	199	227	256	298	360	480	2 994	64.64
Average compression on 12-inch length		.0040	.0054	.0066	.0075	.0083	.0090	.0100	.0109	.0117	.0125	.0135	.0144	.0154	.0166	.0178	.0192	.0208	.0226	.0246	.0268	.0303	.0346	.0408	.0495	.0663	3 027	64.44
172	12	.0014	.0026	.0033	.0040	48	56	65	72	80	88	99	116	136	160	190	220	250	280	311	344	436	530	.....	.....	.....	.....	2 540	144.48
173	12	.0016	31	44	56	64	71	78	85	82	100	107	114	123	131	139	147	158	170	177	190	229	281	339	410	.....	.....	2 840	144.36
Average 12 inches		.0015	.0028	.0033	.0048	.0036	.0063	.0072	.0079	.0086	.0094	.0103	.0115	0.130	.0145	.0165	.0184	.0204	.0225	.0244	.0267	.0333	.0400	.....	.....	.....	.....	2 690	144.42
174	16	.0011	21	29	36	48	54	62	71	78	87	96	106	118	129	142	151	178	188	206	228	258	352	424	594	.....	2 880	259.37
175	16	.0014	22	30	40	48	54	60	66	73	82	88	96	108	115	124	138	150	158	168	186	216	272	308	370	466	3 077	260.01
Average compression on 12 inch length		.0010	.0015	.0023	.0029	.0036	.0041	.0046	.0052	.0057	.0064	.0069	.0076	.0085	.0092	.0100	.0108	.0123	.0130	.0140	.0155	.0182	.0234	.0255	.0362	.....	2 979	259.69
Total average compression,		.0022	33	42	51	58	65	72	80	87	92	102	112	123	134	148	161	178	194	210	230	273	327	.....	.....	.....	2 899	.....

TABLE No. 4.

CUBES OF ROSENDALE CEMENT MORTAR (1½ sand and 1 cement), forty-six months old; tested between steel faces packed with plaster of paris.

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No. of Test.	Kind.	Pressures in Pounds per Square Inch.																Ultimate Pounds per Square Inch.	Area Square Inches.
		100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600		
	Inches.																		
120	8	.0017	.0027	.0033	.0040	.0053	.0068	.0077	.0087	.0101	.0117	.0129	.0144	.0163	.0182	.0210	.0245	1 640	64.64
121	8	.0022	.0039	.0050	.0065	.0074	.0085	.0098	.0106	.0117	.0129	.0141	.0156	.0169	.0190	.0205	.0247	1 852	64.80
Average compression on 12 inches		.0030	.0049	.0063	.0079	.0096	.0115	.0132	.0145	.0163	.0184	.0202	.0225	.0249	.0279	.0312	.0369	1 746	.....
123	12	.0020	.0040	.0056	.0070	.0090	.0110	.0131	.0162	.0190	.0234	.0290	.0360	.0480	.....	.....	.....	1 366	144.48
124	16	.0031	.0060	.0080	.0100	.0120	.0140	.0160	.0190	.0228	.0272	.0318	.0388	.....	.....	.....	.....	1 254	256.16
125	16	.0021	.0050	.0071	.0091	.0111	.0133	.0157	.0184	.0218	.0260	.0320	.0440	.....	.....	.....	.....	1 240	258.08
Average compression on 12 inches		.0019	.0041	.0057	.0072	.0087	.0103	.0119	.0139	.0167	.0200	.0239	.0310	.....	.....	.....	.....	1 247	.....
Average compression of all		.0023	.0043	.0059	.0074	.0091	.0109	.0127	.0146	.0170	.0200	.0254	.0286	.0326	.....	.....	.....	1 386	.....

CUBES OF ROSENDALE CEMENT MORTAR (1 cement and 3 sand), forty-six months old.

140	8	.0031	.0054	.0074	.0094	.0102	.0147	.0182	.0258	.....	.....	.....	.....	.....	.....	.....	.....	848	64.
141	8	.0037	.0058	.0074	.0094	.0120	.0153	.0182	.....	.....	.....	.....	.....	.....	.....	.....	.....	732	64.56
Average compression on 12 inches		.0051	.0083	.0111	.0141	.0167	.0225	.0273	.0387	.....	.....	.....	.....	.....	.....	.....	.....	790	.....
142	12	.0020	.0040	.0060	.0080	.0114	.0167	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	680	144.96
143	12	.0018	.0040	.0060	.0085	.0130	.0192	.0260	.....	.....	.....	.....	.....	.....	.....	.....	.....	695	146.17
Average compression on 12 inches		.0019	.0040	.0060	.0083	.0122	.0180	.0260	.....	.....	.....	.....	.....	.....	.....	.....	.....	688	.....
144	16	.0027	.0053	.0083	.0113	.0160	.0220	.0330	.....	.....	.....	.....	.....	.....	.....	.....	.....	749	259.37
145	16	.0043	.0075	.0108	.0149	.0190	.0280	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	687	257.12
Average compression on 12 inches		.0027	.0048	.0072	.0098	.0131	.0188	.0247	.....	.....	.....	.....	.....	.....	.....	.....	.....	718	.....
Average compression of all		.0032	.0057	.0081	.0108	.0140	.0197	.0260	.0387	.....	.....	.....	.....	.....	.....	.....	.....	711	.....

TABLE No. 5.

Cubes of Rosendale Cement Concrete (1 cement, 3 sand and 6 broken stone); forty-six months old.

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No. of Test.	Kind.	Pressure in Pounds per Square Inch.													Ultimate.
		100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	
	Inches.															
150	8	.0071	.0100	.0121	.0149	.0175	.0209	.0266	.0374	.....	.....	.....	.....	.....	.....	879
151	8	.0028	.0050	.0070	.0090	.0110	.0140	.0177	.0270	.....	.....	.....	.....	.....	.....	844
Average compression on 12 inches		.0075	.0133	.0144	.0180	.0214	.0261	.0333	.0483	.....	.....	.....	.....	.....	.....	862
152	12	.0017	.0040	.0055	.0077	.0110	.0163	.0328	.....	.....	.....	.....	.....	.....	.....	775
153	12	.0018	.0038	.0054	.0074	.0096	.0141	.0280	.....	.....	.....	.....	.....	.....	.....	757
Average compression on 12 inches		.0018	.0039	.0055	.0076	.0103	.0152	.0304	.....	.....	.....	.....	.....	.....	.....	766
154	16	.0032	.0062	.0090	.0120	.0147	.0189	.0242	.0337	.....	.....	.....	.....	.....	.....	858
155	16	.0023	.0045	.0065	.0085	.0120	.0168	.0270	.0499	.....	.....	.....	.....	.....	.....	828
Average compression on 12 inches		.0022	.0041	.0059	.0077	.0100	.0134	.0112	.0303	.....	.....	.....	.....	.....	.....	843
Average compression of all		.0038	.0064	.0086	.0111	.0139	.0182	.0274	.0393	.....	.....	.....	.....	.....	.....	824
1 cement, 2 sand, 3 gravel and 4 broken stone; twenty-two months old.																
177	10	.0011	.0030	.0050	.0068	.0088	.0110	.0141	.0182	.0240	.0335	.....	.....	.....	.....	.....
Average compression on 12 inches		.0013	.0036	.0060	.0082	.0106	.0132	.0169	.0220	.0288	.0402	.....	.....	.....	.....	1 182
109	12	.0026	.0050	.0070	.0097	.0126	.0153	.0199	.0253	.0335	.0487	.0680	.....	.....	.....	1 113
113	16	.0029	.0048	.0069	.0089	.0119	.0163	.0238	.0360	.0518	.....	.....	.....	.....	.....	.....
Average compression on 12 inches		.0022	.0036	.0052	.0067	.0089	.0122	.0177	.0270	.0389	.....	.....	.....	.....	.....	1 039
115	18	.0033	.0062	.0087	.0109	.0144	.0179	.0223	.0303	.0430	.0670	.....	.....	.....	.....	.....
Average compression on 12 inches		.0022	.0042	.0058	.0073	.0096	.0119	.0149	.0202	.0287	.0447	.....	.....	.....	.....	1 044
Average compression of all		.0021	.0041	.0060	.0080	.0104	.0131	.0174	.0236	.325	.0445	.0680	.....	.....	.....	1 095
1 cement, 1½ sand and 6 broken stone; forty-six months old.																
130	8	.0028	.0040	.0050	.0060	.0075	.0089	.0105	.0131	.0165	.0212	.0275	.0359	.0471	.....	1 352
131	8	.0050	.0080	.0095	.0110	.0129	.0150	.0171	.0200	.0234	.0273	.0322	.0374	.0441	.0600	1 532
Average compression on 12 inches		.0058	.0090	.0109	.0128	.0153	.0180	.0207	.0249	.0300	.0364	.0448	.0550	.0674	.0900	1 442
132	12	.0015	.0030	.0040	.0058	.0071	.0070	.0112	.0142	.0172	.0218	.0268	.0336	.0410	.0560	1 503
133	12	.0027	.0057	.0090	.0110	.0130	.0145	.0164	.0197	.0221	.0260	.0316	.0352	.0417	.0518	1 617
Average compression on 12 inches		.0021	.0044	.0065	.0084	.0101	.0118	.0138	.0170	.0197	.0239	.0292	.0344	.0414	.0539	1 560
134	16	.0039	.0057	.0070	.0082	.0095	.0110	.0130	.0162	.0205	.0272	.0375	.0530	.0760	.1011	1 466
135	16	.0020	.0040	.0071	.0070	.0085	.0106	.0130	.0159	.0196	.0259	.0330	.0488	.0622	.0873	1 429
Average compression on 12 inches		.0023	.0037	.0046	.0057	.0068	.0081	.0098	.0111	.0151	.0200	.0265	.0382	.0518	.0706	1 448
Average compression of all		.0034	.0057	.0073	.0089	.0107	.0126	.0148	.0180	.0216	.0268	.0335	.0425	.0335	.0715	1 483

TABLE No. 6.

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Brick Piers Laid in Cement Mortar. Compressions given for 12 inches length in inches.

No. of Tests.	Size of Piers. (Nominal.)	Total Height.	Gauged Height.	Area of Section.	No. of Courses.	Thickness of Joints.	Age of Specimen.	Pressures in Pounds per Square Inch. 100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 800	1 900	2 000	2 200	2 400	2 600	2 800	3 000	3 200	3 600	Rupture in Pounds per Square Inch.	Kind of Brick.	Pier, How Built.	Proportions of Cement, Etc.
	Sq. In.	In.	In.	Sq. In.		In.	Months.																														
12	8	.....	16.24	57.76	7	$\frac{1}{2}$	15	.0016	.0030	.0047	.0064	.0083	.0101	.0117	.0141	.0165	.0186	.0207	.0225	.0235	.0258	.0281	.0293	.0307	.0324	.0368	.0378	.0412	.0444	.0488	.0541	.0577	.0609	.0720	3 776	Face.	Solid.	1 Portland to 2 sand.
228	16	121	100.	25.6	49	$\frac{1}{4}$	24	.0001	6	15	23	33	34	39	43	50	58	67	77	88	100	113	130	149	172	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 887	Common.	"	" " "
229	12	120	100.	138.06	48	$\frac{1}{4}$	24	.0001	7	16	25	34	42	49	56	64	70	80	89	97	111	127	139	154	171	.....	.....	.....	.....	.....	.....	.....	.....	.....	2 003	"	"	" " "
226	12	119.3	100.	132.25	51	$\frac{5}{16}$	$23\frac{1}{2}$	.0001	6	11	16	21	26	32	38	45	52	60	70	79	88	100	116	125	140	154	177	.....	.....	.....	.....	.....	.....	.....	2 253	Face.	"	" " "
221	8	80	50.	57.76	35	$\frac{1}{2}$	23	.0001	6	12	19	27	34	41	59	66	76	85	94	102	111	126	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2 249	"	"	" " "
Average at 23 to 24 months								.0001	6	13	21	29	34	40	49	56	64	73	82	91	102	116	128	143	161	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	" "
286	12	23.50	23.50	132.25	10	$\frac{1}{2}$	$18\frac{1}{2}$	.0008	20	30	46	69	96	117	148	162	182	200	227	236	250	276	303	311	321	340	347	372	405	447	473	500	540	719	3 670	Face.	Solid.	
287	16	.....	31 85	256.	13	$\frac{1}{2}$	$18\frac{1}{2}$	.0005	12	25	39	56	83	117	183	212	241	280	330	350	372	396	433	450	470	492	578	658	.....	.....	.....	.....	.....	.....	.....	.....	Common.	"	" " "
Average at $18\frac{1}{2}$ months								.0007	16	28	43	63	90	117	166	187	212	240	279	293	312	336	368	381	396	416	463	515	.....	.....	.....	.....	.....	.....	.....	.....	.....	" "
201	12	$73\frac{3}{8}$	50.	144.	30	$\frac{5}{16}$	$20\frac{1}{2}$	.0002	10	22	42	61	82	108	130	151	177	209	239	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 646	Bay State.	Solid.	1 Rosendale, 2 lime, 6 sand.
203	12	$72\frac{1}{8}$	50.	144.	30	$\frac{5}{16}$	20	.0002	8	13	26	37	48	62	72	84	98	113	127	144	168	183	204	223	257	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 972	"	"	" " 2 sand.
204	12	$72\frac{0}{10}$	50.	144.	29	$\frac{5}{16}$	20	.0001	6	14	23	34	47	60	72	86	101	120	134	150	175	192	212	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 792	"	"	1 Portland, 2 sand.
200	12	$73\frac{3}{8}$	50.	144.	30	$\frac{5}{16}$	$20\frac{1}{2}$	.0001	10	26	45	64	84	103	125	144	165	193	215	240	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 411	"	"	" 2 lime, 6 sand.
190	12	72	50.	144	30	$\frac{5}{16}$	$19\frac{1}{2}$	.0000	3	11	19	29	38	47	55	62	72	84	94	100	120	129	138	150	162	173	186	.....	.....	.....	.....	.....	.....	.....	2 375	"	"	Neat Portland.

Terra Cotta Cylinder.

	.....	$48\frac{0}{10}$	30	.....	.....	.....	.....	.0003	11	21	33	44	63	72	96	Fluted terra cotta cylinder of 8 segments, each $5\frac{1}{2}$ inches high, joined by cement, $15\frac{1}{4}$ outside diameter, with $5\frac{7}{10}$ inches core.			881	Compressive strength of segments was 3 432 pounds.

TABLE No. 7.

BRICK PIERS LAID IN LIME MORTAR (1 lime and 3 sand). Compressions given for 12 inches length in inches.

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	Size of Pier. (Nominal.)	Total Height.	Gauged Height.	Area of Section.	No. of Courses.	Thickness of Joints.	Age of Specimen.	Pressures in Pounds per Square Inch. 100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 800	1 900	2 000	2 200	2 400	Rupture in Pounds per Square Inch.	Kinds of Brick.	Pier, How Built.
	Sq. in.	In.	In.	Sq. in.		In.	Months.																								
11	8	.....	16½	57.	7	.....	15	.0051	.0098	.0149	.0195	.0246	.0289	.0329	.0403	.0453	.0500	.0557	.0616	.0664	.0713	.0766	.0861	.0933	.0955	.1003	.1090	.1249	.1335	2 520	Face.	Solid.
10	8	.....	16.48	60.8	7	.....	15	.0150	244	322	395	462	528	582	646	712	766	824	926	989	.1072	.1122	.1165	.1217	.1272	.1342	.1421	.....	.....	2 440	Common.	"
erage at 15 months								.0101	.0171	236	295	354	409	456	525	583	633	691	771	827	893	944	1013	.1075	.1114	.1173	.1256	.....	.....	.....	.....
83	12	.....	23.05	132.25	10	.....	18½	.0021	57	94	131	168	213	252	324	381	438	522	671	719	771	874	.....	.....	.....	.....	.....	.....	.....	1 947	Face.	"
94	12	.....	22.04	113.76	10	.....	18½	.0052	109	158	206	259	307	374	429	518	562	624	682	736	798	863	926	986	.....	.....	.....	.....	.....	1 990	"	Hollow, with interior space 4¼ x 4¼ in.
81	12	.....	23.90	138.06	10	.....	18½	.0050	138	226	316	404	498	605	673	763	856	932	979	.1082	.1148	.....	.....	.....	.....	.....	.....	.....	.....	2 150	Common.	Solid.
82	12	.....	23.90	119.58	10	.....	18½	.0015	60	130	198	260	344	439	540	636	742	838	931	.1038	.1123	.....	.....	.....	.....	.....	.....	.....	.....	2 050	"	Hollow. (Space 4½ x 4½ in.)
85	12	.....	24.10	146.41	10	.....	18½	.0053	133	200	274	339	410	505	546	632	736	826	933	.1071	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 370	Bay State.	Solid.
erage at 18½ months								.0038	99	162	225	286	354	435	502	586	667	748	831	929	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
88	12	72½	50	144.	30	3/16	19½	.0010	51	100	152	207	263	332	382	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 133	Bay State.	"
91	12	72¼	50	144.	30	3/16	20	.0007	22	60	110	158	212	281	326	386	418	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 331	"	"
92	12	73	50	156¾	19 (On edge.)	⅛	20	.0005	27	60	94	129	161	197	233	267	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 211	"	"
erage at 19½ to 20 months								.0007	33	73	118	165	212	270	313	329	448	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
80	8	80	50	57.76	35	1/8	23	.0003	12	31	66	105	146	175	212	253	294	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 877	Face.	"
95	12	94¼	80	144.	39	1/8	23½	.0005	26	71	116	163	213	265	329	381	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 174	Bay State.	"
87	12	119.6	100	144.	49	1/8	23½	.0004	20	64	123	188	255	329	410	498	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	924	"	"
90	12	120⅜	100	115⅜	50	¼	24	.0002	17	52	113	175	242	301	372	438	502	565	638	700	788	.....	.....	.....	.....	.....	.....	.....	.....	1 587	Common.	Hollow. (Space 4¾ x 4¾ in.)
81	12	117⅜	100	138.06	49	¼	24	.0004	24	109	216	356	550	650	739	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 118	"	Solid.
92	12	119⅞	100	132.25	52	1/8 to 3/16	24	.0002	13	38	81	131	182	240	295	350	398	457	510	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 511	Face.	"
84	12	119⅛	100	115.44	52	⅛	24	.0001	17	51	88	122	159	193	232	272	314	355	398	410	490	530	579	600	.....	.....	.....	.....	.....	1 807	"	Hollow. (Space 4 1/10 x 4 1/10 in.)
93	12 x 16	120⅛	100	192.	49	⅛	24	.0000	24	103	202	306	384	534	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	773	Bay State.	Solid.
95	8 x 12	120¾	100	96.	49	⅛	24	.0000	19	93	162	249	332	413	512	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	940	"	"
rage at 23 to 24 months								.0002	19	68	129	199	274	344	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE No. 8.

BRICK PIERS AND BASE WITH BLUESTONE CAP.—Compressions in inches for 12 inches in length.

Caps, 2.75 to 3.10 inches thick; bases, 2.75 to 4.15 inches thick; bricks, 8 x 3½ x 2¼ inches, set in Newark Company's Rosendale cement (1 cement to 2 sand); twenty-two months old; piers packed with brass strips where needed.

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No. of Test.	Kind.	Pressures in Pounds per Square Inch.																			Ultimate.	Area in Square Inches.	Height.
		100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 800	1 900	2 000			
																							Inch.
78	12 x 12	.0018	38	56	72	85	94	115	131	140	163	184	201	223	248	278	307	342	394	454	.....	2 021	144.0	22.42
79	12 x 12	.0019	41	63	83	101	120	138	158	179	195	217	238	263	291	317	391	.....	.....	.....	.....	1 821	142.8	22.08
80	12 x 12	.0029	53	71	89	104	118	135	153	169	197	222	243	271	304	342	384	444	.....	.....	.....	1 805	144.0	22.58
81	12 x 12	.0016	32	46	59	71	87	102	117	133	150	173	191	210	234	268	291	339	394	.....	.....	1 944	144.0	22.50
82	12 x 12	.0034	66	86	110	129	148	166	187	211	232	260	283	310	347	396	434	.....	.....	.....	.....	1 736	144.0	23.22
83	12 x 12	.0033	42	58	65	89	106	124	143	163	187	214	241	272	308	367	416	507	.....	.....	.....	1 780	141.0	21.98
Average		.0025	45	63	80	96	112	130	148	166	187	212	233	258	289	328	370	.....	.....	.....	.....	1 851	.....	.....

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TABLE No. 9.

CUBES OF HAVERSTRAW FREESTONE, set in plaster of paris and tested between steel cushions. Compressions in inches for 12 inches in length.

| No. of Test. | Kind. | Pressures in Pounds per Square Inch. | | |

PLATE LXVIII.
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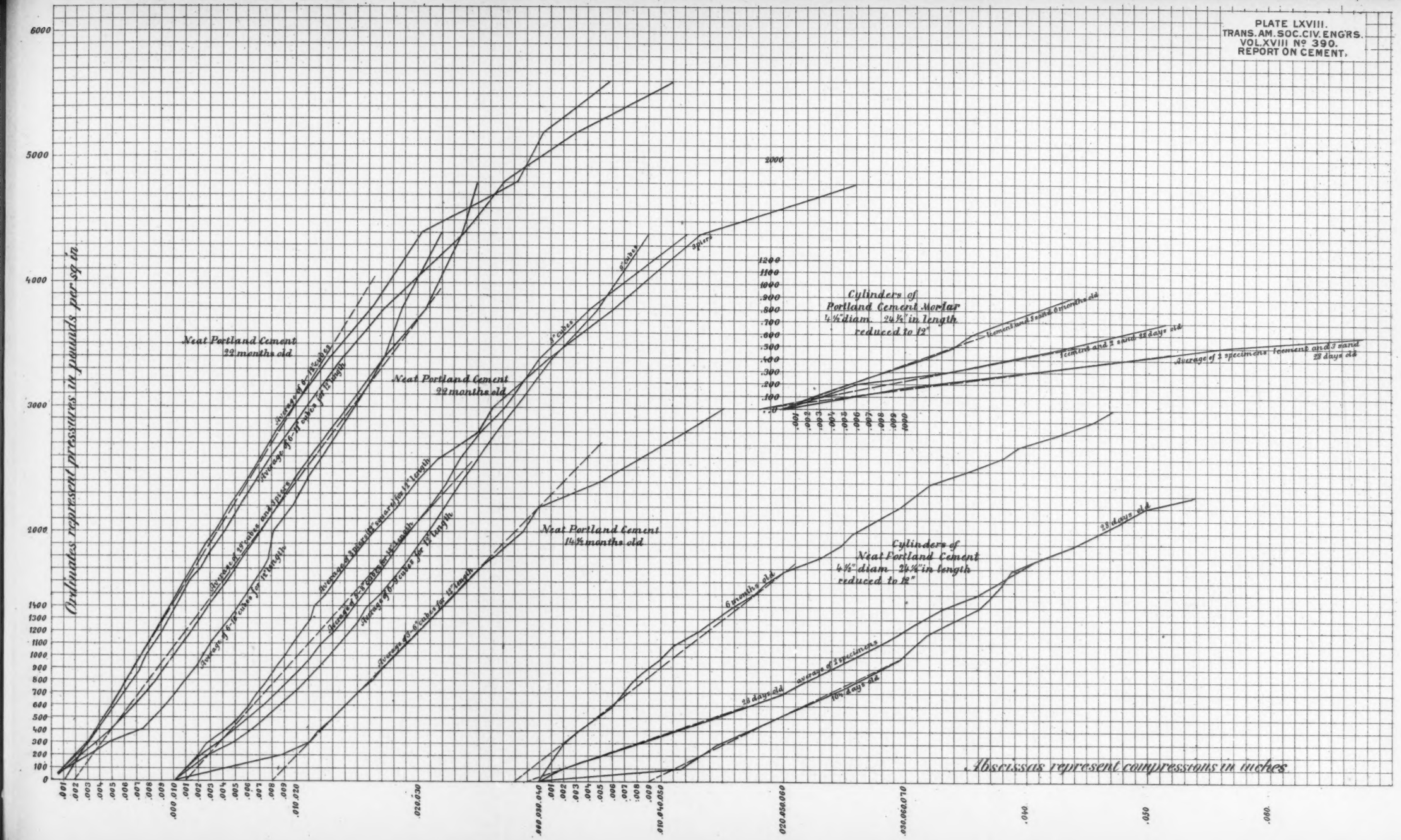
Ordinates represent pressures in pounds per sq in
Neat Portland Cement
22 months old
Average of 6 3"cubes
Average of 3 3"cubes and 3 prisms
Average of 6 3"cubes for 12" length
Neat Portland Cement
22 months old
Average of 3 3"cubes and 3 prisms 12" in length
Average of 3 3"cubes for 12" length
Average of 6 3"cubes for 12" length
Neat Portland Cement
14½ months old
3 cubes
3 prisms
Cylinders of
Portland Cement Mortar
4½" diam. 24½" in length
reduced to 12"
1 cement and 3 sand 6 months old
1 cement and 2 sand 28 days old
Average of 2 specimens 1 cement and 3 sand
28 days old
Cylinders of
Neat Portland Cement
4½" diam. 24½" in length
reduced to 12"
6 months old
28 days old
Average of 3 specimens
28 days old
Abscissas represent compressions in inches

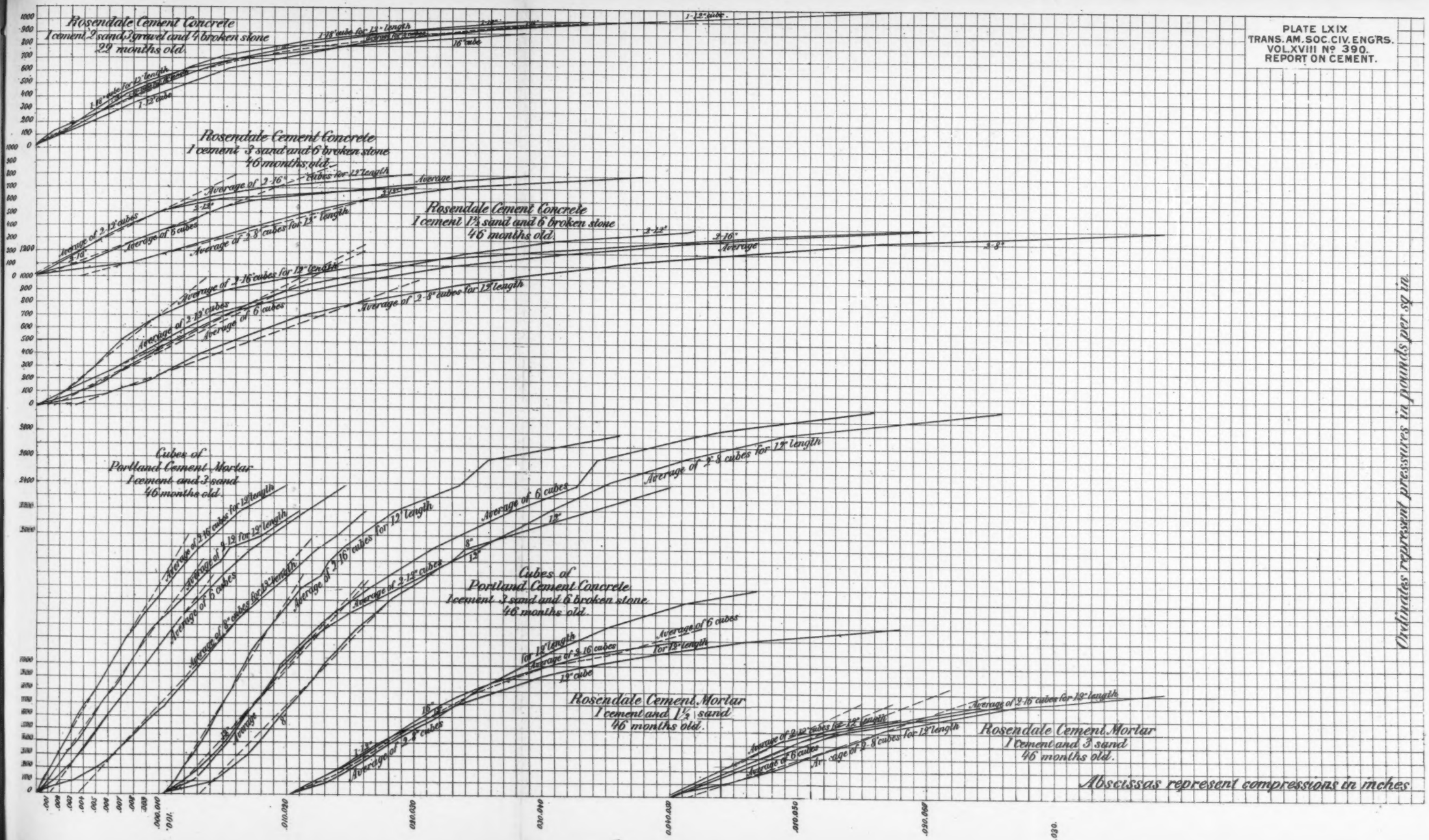
PLATE LXIX
TRANS. AM. SOC. CIV. ENG'RS.
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REPORT ON CEMENT.
Rosendale Cement Concrete
1 cement 2 sand 3 gravel and 4 broken stone
29 months old.
Rosendale Cement Concrete
1 cement 3 sand and 6 broken stone
46 months old.
Rosendale Cement Concrete
1 cement 1½ sand and 6 broken stone
46 months old.
Cubes of
Portland Cement Mortar
1 cement and 3 sand
46 months old.
Cubes of
Portland Cement Concrete
1 cement 3 sand and 6 broken stone
46 months old.
Rosendale Cement Mortar
1 cement and 1½ sand
46 months old.
Rosendale Cement Mortar
1 cement and 3 sand
46 months old.
Ordinates represent pressures in pounds per sq. in.
Abscissas represent compressions in inches

PLATE LXX
TRANS. AM. SOC. CIV. ENGRS.
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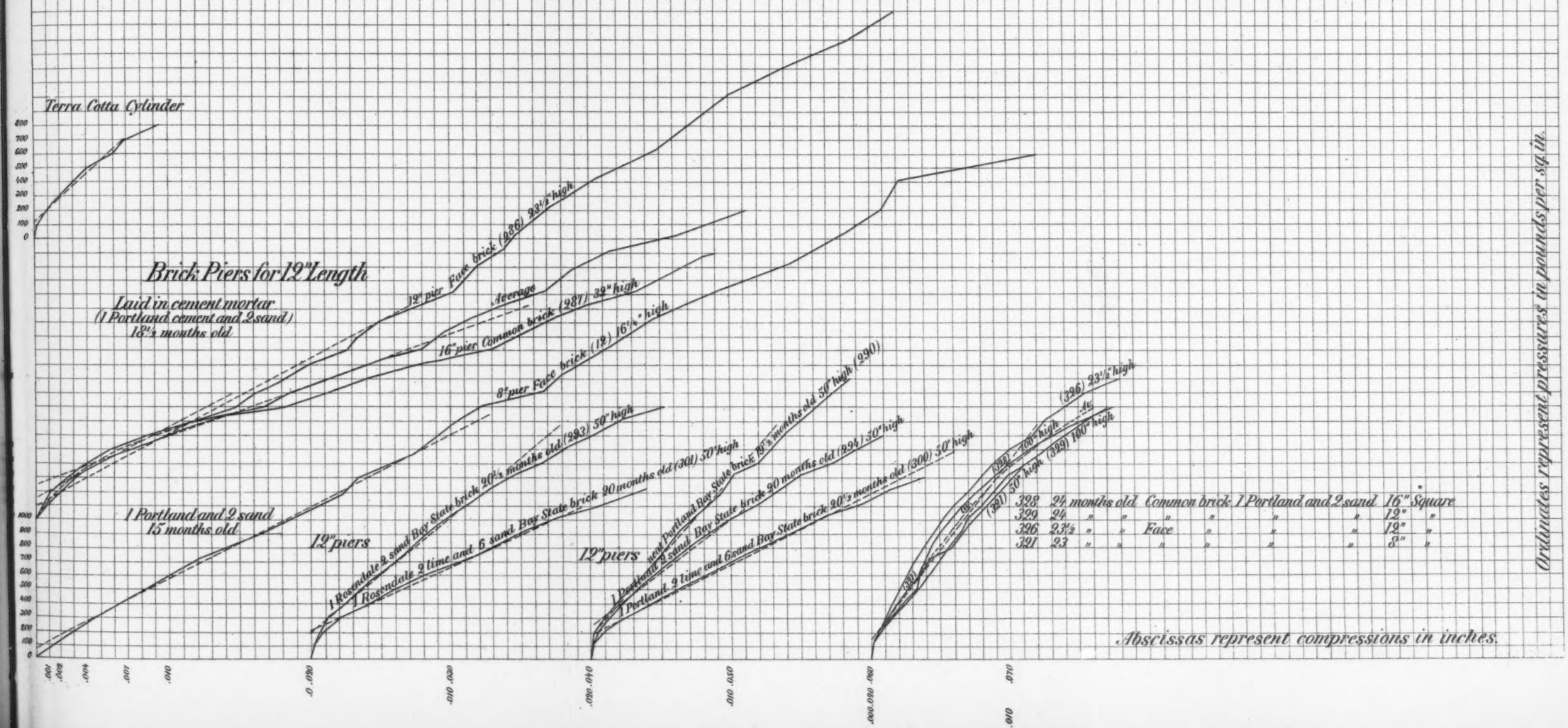
Terra Cotta Cylinder
Brick Piers for 12" Length
Laid in cement mortar
(1 Portland cement and 2 sand)
12½ months old
12" pier Face brick (286) 23½" high
Average
16" pier Common brick (287) 32" high
8" pier Face brick (12) 16½" high
1 Portland and 2 sand
15 months old
12" piers
1 Rosendale 2 sand Bay State brick 20½ months old (293) 50" high
1 Rosendale 2 lime and 6 sand Bay State brick 20 months old (301) 50" high
12" piers
1 Portland cement Portland Bay State brick 19½ months old 50" high (290)
1 Portland 2 sand Bay State brick 20 months old (295) 50" high
1 Portland 2 lime and 6 sand Bay State brick 20½ months old (300) 50" high
(326) 23½" high
(329) 100" high
(321) 50" high
328 2½ months old Common brick 1 Portland and 2 sand 16" Square
329 24 " " " " " " 12" "
326 23½ " " Face " " " 12" "
321 23 " " " " " " 8" "
Ordinates represent pressures in pounds per sq. in.
Abscissas represent compressions in inches.

PLATE LXXI.
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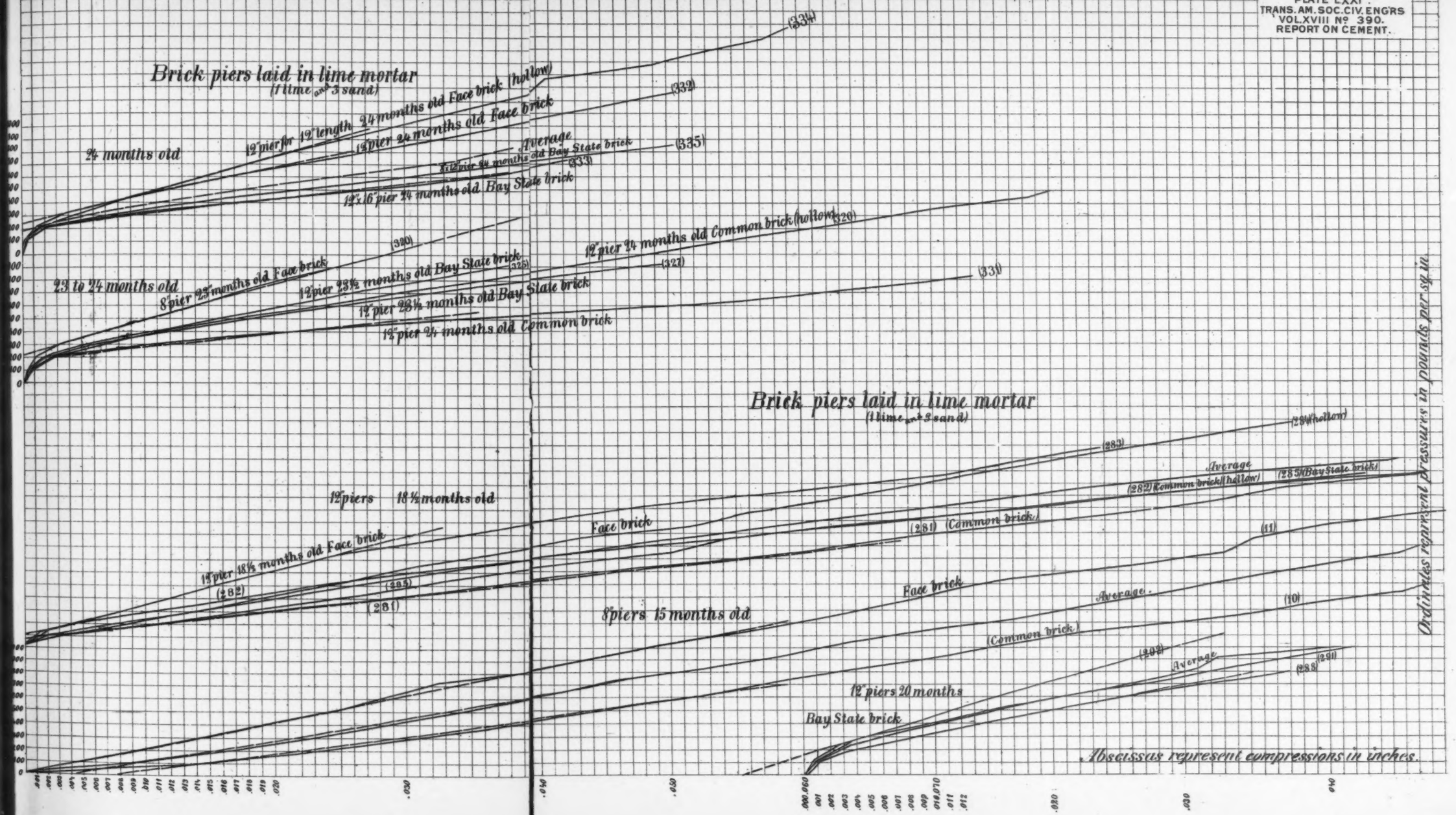
Brick piers laid in lime mortar
(1 lime, 2½ sand)
24 months old
12" pier for 12" length 24 months old Face brick (hollow) (334)
12" pier 24 months old Face brick (332)
Average
12"x12" pier 24 months old Bay State brick (335)
12"x16" pier 24 months old Bay State brick (333)
23 to 24 months old
8" pier 23" months old Face brick (320)
12" pier 23½ months old Bay State brick (325)
12" pier 23½ months old Bay State brick
12" pier 24 months old Common brick (hollow) (329)
12" pier 24 months old Common brick (327)
(331)
12" piers 18½ months old
12" pier 18½ months old Face brick
(282)
(283)
(281)
Face brick
(284) hollow
(283)
Average
(282) Common brick (hollow)
(285) Bay State brick
(281) (Common brick)
Brick piers laid in lime mortar
(1 lime, 2½ sand)
8" piers 15 months old
Face brick
(11)
Average
(10)
(Common brick)
(292)
Average
(288)
(291)
12" piers 20 months
Bay State brick
Abscissas represent compressions in inches.
Ordinates represent pressures in pounds per sq. in.

PLATE LXXII.
TRANS. AM. SOC. CIV. ENG'RS.
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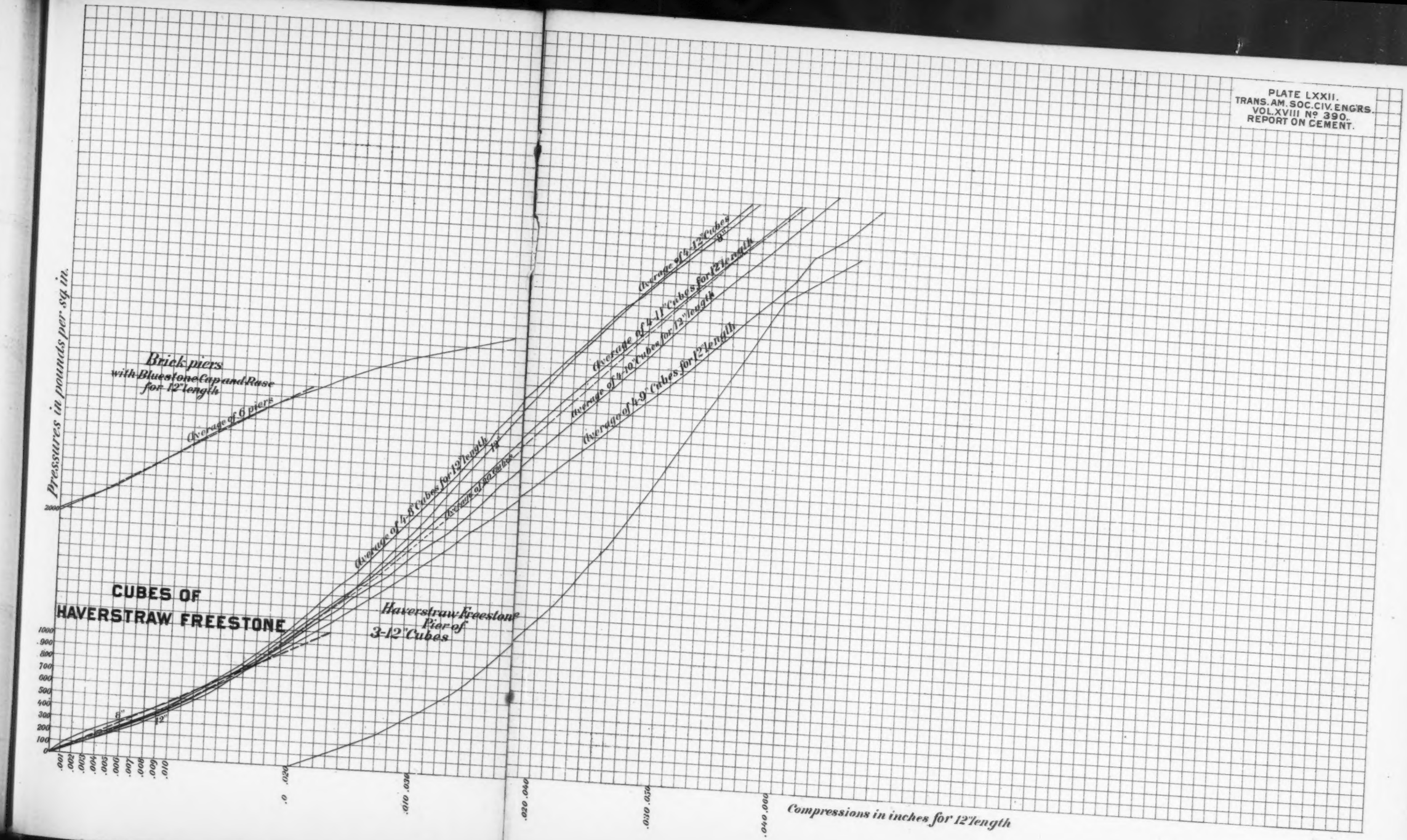
Pressures in pounds per sq. in.
Brick piers
with Bluestone Cap and Base
for 12" length
Average of 6 piers
Average of 4-8" Cubes for 12" length
Average of 4-12" Cubes
CUBES OF
HAVERSTRAW FREESTONE
Haverstraw Freestone
Pier of
3-12" Cubes
Average of 4-11" Cubes for 12" length
Average of 4-10" Cubes for 12" length
Average of 4-9" Cubes for 12" length
Compressions in inches for 12" length

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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(Vol. XVIII.—June, 1888.)

THE MANUFACTURE OF BRICK.

I.—THE BRICK INDUSTRY ABOUT NEW YORK CITY. By CALVIN TOMKINS.
II.—BRICK MANUFACTURE NEAR CHICAGO. By D. V. PURINGTON.
III.—SLATE BRICKS. By JOSÉ R. VILLALON.
IV.—NOTE ON BRICK MAKING IN SINALOA, MEXICO. By SEÑOR DON FRAN. SOSA Y AVELA.
V.—DISCUSSION ON THE MANUFACTURE OF BRICK.

THE BRICK INDUSTRY ABOUT NEW YORK CITY.

By CALVIN TOMKINS, Assoc. Am. Soc. C. E.
READ MARCH 16TH, 1887.

The Dutchmen who came to New York brought their bricks with them, and it was not till the financial depression which succeeded the Revolutionary War had passed away that the manufacture of brick was established in this vicinity.

Previous to the present century what few bricks were used for the better class of structures continued to be imported at ballast rates from Holland and England. The freight being nominal, the cost would not be so great as might at first be supposed.

These old bricks are of a yellow-red color, smaller, and in particular, thinner than the average brick now used. When fractured, they indicate the presence of an excess of loamy clay and an insufficiency of sand. They generally appear to be under-burnt. As a rule they are in a good state of preservation, which is largely to be attributed to the custom of painting the exposed surfaces. Some of the bricks in the Treason Hill House, near Haverstraw, are stamped Haverstraw, 1772, and it is probable that the industry was irregularly carried on along the Hudson and North Jersey shores for some time previous to 1815, when James Wood left Sing Sing, where he then made brick, and started a brick-yard at Haverstraw. It is to the enterprise of this man that the manufacture of brick owes its first impetus.

In 1826 he introduced the custom of mixing anthracite dust with the clay before molding. As a result of this improvement, the time necessary to burn a kiln of brick was reduced from a period of two weeks or more to one week; the quantity of cord wood required was cut down three-fourths; and the expense, total, of a burn reduced to two-fifths of the former cost. The green bricks being sufficiently porous to admit air to the particles of coal dust, cause the brick to burn equally throughout; and the wood now burnt under the arches is simply that which is necessary to raise the temperature of the brick, and maintain it at a point where the coal will ignite. Mr. Wood secured a patent on his process, but was not able to resist the combined pressure of other manufacturers who adopted his methods, and who at last began to realize a fair return from the industry. The quality of bricks improved while prices fell off, and a growing demand brought about an increased output, which still continues to run up the totals of the yearly product.

In 1849 the first steam molding machines were introduced by Ver Valen of Haverstraw. These early machines were very defective, but improvements were soon made, and the old-time process of molding by hand has long since been discarded. With the exception of the two changes just noticed, the methods of brick-making have practically remained unchanged in this vicinity.

Bricks which come to the New York market are classed as follows, according to locality, viz.:

Haverstraws, which include all bricks made on the Hudson below the Highlands.

Up Rivers, or those made on the Hudson above the Highlands.

Jerseys, which are manufactured along the north coast of New Jersey.

Hackensacks, which are manufactured on the Hackensack River near Hackensack, N. J.

Long Islands, which are manufactured along the north shore of Long Island.

Staten Islands, which are manufactured along the Freshkills of Staten Island.

Front bricks are sold here from Philadelphia, Trenton and Baltimore, and a second-class front is made on the Hudson at Verplanks and Croton. These last are known as Croton fronts.

Fire-bricks and the hollow bricks used for fire-proofing buildings are made in the district about Woodbridge, N. J., and on Staten Island.

Buff-colored bricks, such as were used in the construction of the Cotton Exchange and *Post* Buildings of this city, are made of clays deposited about Amboy and Sayerville, N. J., and Glens Falls, N. Y., which are comparatively free from the oxides of iron.

Excellent enameled bricks of various colors are made at Croton.

Clay is defined as a silicate of alumina containing an excess of free silica. It is primarily caused by the action of carbonic acid and water present in the atmosphere, which combine with alkalies of the feldspar in granitic rocks. Weathering accelerates the decomposition; the soluble products, consisting of alkaline carbonates, being washed away, leaving the clay. The clay about New York is generally superimposed on rock or gravel, and is, as a rule, overlaid with sand, which is as necessary as clay to the manufacture of good brick.

The north shore of Long Island, from Glen Cove to Greenport, is girt with meadows and headlands of drift. These deposits of clay and sand are worked at or near Locust Valley, Cold Spring, Huntington, Greenlawn and Northport.

The Long Island clays are variegated in color, and the bricks made from them are of excellent quality when proper care is taken. Few, however, come to the New York market, and then only when other bricks are scarce. The output is not large, and is principally absorbed by the towns of Long Island and those located along the Connecticut shore.

Bricks of good quality have recently been made at Fisher's Island, and many of them have been used in the construction of the new aqueduct.

Few bricks are made along the shore of Connecticut, but a few miles back from the coast good bricks are made and shipped by rail to neighboring towns.

Three or four small yards are located on the Freshkills at Staten Island. Their output is small, of inferior quality, and gray in color.

They are only shipped in the winter season when ice interferes with shipments from other points.

The bricks made along the coast of New Jersey about Keyport, South River, and Perth Amboy, are of very irregular character. The trade divides them into four classes, known respectively as

Dark hards, which have been highly burned, are very dense, and of a dark red color.

Light hards, which have not been subjected to such an intense heat in the kilns as the former class, and which are lighter in color, but still hard and durable.

Grays, which may be considered as under-burnt bricks, or bricks made from clay not containing sufficient ferruginous matter to afford a proper color.

Sulphur bricks, which are made from clay containing an excess of pyrites, and which are more or less swelled, warped, or spotted by the oxidation of this compound during ignition.

Nearly all of the bricks known as Jerseys show evidences of the presence of sulphate of iron in the clays of which they are made, and this is the most serious objection that can be raised against them. Unless oxidation of the pyrites is completed during the process of burning it will continue in the presence of the air, and is likely to impair the strength of the brick by expansion, resulting in unbalanced stresses.

The bluish-black spots and vitrified blotches which affect the surface more or less of all these bricks, are due to the same cause, and for this reason they are generally unfitted for wall work, where appearance is a consideration.

As a rule, Jersey bricks are rough and not so well made as the Hackensacks and those made in the upper and lower Hudson valleys. The lack of plenty of good accessible sand in the vicinity of these brick-yards occasions the use of a larger proportion of clay to sand than is generally employed elsewhere, and causes the brick to shrink and sometimes to warp slightly. However shrinkage is made up for by increasing the sizes of the moulds, and these bricks are fully as large, if not larger, than the average brick. Many of these yards produce a strong, tough brick.

Great improvements have been made in the process of manufacture, and the industry is probably more rationally pursued in this section than elsewhere.

The principal change affected has been the use of coal under the arches in place of wood.

The best Jersey bricks are frequently preferred on account of their greater density.

A brick is now being manufactured by a new process near Keyport, which shows no sulphur spots, which appears to be regularly made, and in which very little sand is used. It is not as yet on the market.

Fifteen years ago few, if any, brick were made at Hackensack. Now a number of large yards are engaged in the business. The bricks are a good uniform red color and contain more sand than Jerseys. While they are a fine appearing brick, they frequently lack strength, and unless handled carefully are liable to considerable breakage. They are well liked by the city builders, and the facilities for manufacture are about to be largely increased.

Bricks are made at Mechanicsville and other points along the canal above Albany, but rarely come to this market. Like those made about Greenbush and Albany they are rough and generally not over strong.

At Coeymans, Castleton, and Trust Camp a few bricks are made, and they are fair in quality, but inclined to brittleness, which is the distinguishing characteristic of all up river brick.

Athens, Hudson, and Coxsackie bricks are of a gray-red color; as a rule not well made, nor very strong.

The Hudson bricks generally burn a dirty yellow-red color, and have a somewhat mottled appearance.

Glasco bricks are of better quality, but of a gray tinge, and not carefully made.

The Catskill bricks are probably the strongest which come to the New York market. They are in good demand, but the manufacturers are not sufficiently careful, and regard quantity rather than quality. If carefully burnt the color is a good red, but through carelessness the right shade is not generally attained, and the bricks as a consequence burn a light salmon-red.

Good sand is scarce at Catskill, and a large portion of what is used is scowed up from below the Highlands. As a natural consequence less sand is used with the clay. This is one of the reasons for the superior strength of the bricks. The same cause contributes to the density, and consequent strength, of certain of the Jersey bricks. The bricks shrink in burning however; are somewhat smaller than an average brick, and cannot, even with care, be made as squarely as if more sand should be used. The main cause of the strength of these bricks is said to lie in the clay, and probably this is the true explanation.

Bricks from Saugerties, Port Ewen, and Kingston are generally well made and of good shape. This is especially true of those coming from the latter place. The prevailing color is gray, excepting the Port Ewen bricks, which are a good red.

There is an excess of quicksand in most of these clays, and the resulting bricks are quite brittle. The yards along Newburgh Bay put out the best up river bricks. In fact for the last few years they have approximated both in price and quality to Haverstraws. The color is a good solid red. The bricks are well made and considered to be nearly as strong as those made further down the river.

The Haverstraw influence has made itself felt here more than else-

where, and many of the yards are managed by men who have migrated from the lower bay, and who have been accustomed to the more careful manipulation of clay. These bricks are known as New Windsors, made two miles below Newburgh; Mud-hole brick, made two miles above Newburgh; Fishkills, Low Points, and Dutchess Junction brick.

In discussing the quality of brick as related to locality, what is stated must be received in a very general sense, since local advantages or disadvantages are treated in very different ways by the manufacturer. Good bricks are often made by a careful man out of bad material, while the reverse proposition is equally true. In fact bricks are sold on the name of the maker rather than on the locality of the yard.

Good sand is scarce above the Highlands, and many of the up river yards are supplied in whole or in part with sand from below. To the lack of this material is attributed the general brittleness which distinguishes with few exceptions up river brick. It must be added, however, that carelessness is also a primary cause. Brick manufacture can be conducted for only six months of the year, and the demand comes with a rush which sweeps up bad as well as good brick in ordinary years, and in specially prosperous years cannot find a sufficiency. When this is recalled, it will be remarked how great the tendency must be towards quantity rather than quality. Besides the demand for the best brick is not great. The speculative building interest which constructs most of the city will use what the law allows if it cannot do better on the sly. All the pale brick and lammies are supposed to go to Brooklyn, where the law is more considerate. Architects as a rule specify "best Haverstraw brick," but are liable to be lax in their inspection, and receive whatever comes. Engineers generally introduce the same clause, and if they insist will obtain what is called for.

Of all the common brick other than fronts which come to New York City, those made along Haverstraw Bay, from the Race down to Sing Sing, are considered the best, and the highest prices are realized for them.

Poor bricks as well as good bricks are made through carelessness along this reach of the river; but the fact remains that the average brick made here is superior to brick made at other points. This is due principally to two causes:

First.—The tempering sand in this section is abundant and of the best quality, and the clay is also said to be superior.

Second.—The experience of brick-makers counts for more, as the industry has been of longer standing.

Generally speaking these bricks possess a finer finish and are more regular in form than those made elsewhere. The color is usually a good uniform red, and they are stronger than other bricks.

I shall now proceed to describe the brick industry as it exists along the shores of Haverstraw Bay. With few exceptions the method followed

here is adhered to by the brick-makers in the localities I have already mentioned.

Deposits of clay in this section, when adjacent to navigable water, possess a high value. They can seldom be bought, as the owners prefer to receive the royalties for the clay used per thousand bricks made. The bank-owners are in most instances retired brick-makers; well-to-do men who prefer the assured income of a landlord's position to the anxiety and hard work incident to the proper management of a brick yard.

The brick plant, consisting of machinery, docks, sheds, etc., goes with the use of clay and sand, and all are included under one royalty. The lessee also binds himself to make not less than a certain quantity per annum.

Royalties along Haverstraw Bay average fully one dollar per thousand bricks made. Some yards laboring under natural disadvantages, such as long hauls, inferior or no plant, wet clay pits, etc., range as low as fifty cents, and some specially favored yards bring the owners one dollar and fifty cents per thousand. Up river yards, with the exception of those along Newburgh Bay, command lower rents. These latter bring in nearly the same returns that the Haverstraw yards do, while the limit of others is an approximation to the interest which will maintain the plant. Staten Island, Long Island, Jersey, and many of the up river yards are worked as a rule at first hands, the margin not yet being sufficient to admit of two profits.

To illustrate the value of brick clay *in situ*, I would instance the experience of the North River Construction Company in acquiring the right of way for the West Shore Railroad back of Haverstraw. The line here runs through clay land situated over a mile back from the river, and yet the company found it necessary to pay, for what they expected to obtain at farm land valuations by the acre, four cents per cubic yard for sand and clay, over a strip sixty-six feet wide at the surface and extending down to high water mark, with a slope of 1 to 2.

The Haverstraw blue clay is generally overlaid with a thin layer of yellow clay, which is mixed with the blue before moulding, and which assists in giving to the resulting brick a good color.

Frequently curious stone-like concretions, termed clay dogs, occur in the upper strata of clay, and while they are not found here in sufficient quantities to prove seriously detrimental, they are sometimes objectionable. They consist of a small mass of clay impregnated with carbonate of lime, which is supposed to be conducted downward in solution following the roots of trees and plants. This saturation causes the surrounding clay to harden, and if introduced into the brick results in lime.

After stripping the sand, the stiff clay is cut out in benches and carted to the yard. In some instances before going into the machines the clay and sand are tempered in what is termed a circular pit, about

thirty feet diameter and two and one-half feet depth. A six-foot vertical wheel revolves on a shaft which travels around the pit and gradually works inward from the periphery.

Bricks made by this method are more homogenous, and consequently stronger, but the expense of manufacture is greater. The general method followed is to dump the clay, sand and coal-dust in alternate layers (two of each) into a square sod pit 16 x 12 x 4 feet. A bushel of coal-dust is allowed for each thousand bricks, which, roughly speaking, average from one-third to one-half sand. Sand however is not added by any constant rule, as the clays themselves contain more or less.

In both instances the pits are situated close to the moulding machines, and the mud is shoveled directly into the hopper. Considerable skill is required on the part of the shovelers in the sod pits to introduce the correct proportions of clay and sand.

The use of sand in bricks is analogous to its use in mortar. Clay in burning will shrink considerably, but when well tempered with sand throughout the mass, continuous shrinkage is broken up into separate shrinkages between the grains of sand, consequently the original mould form is not impaired, and the internal stresses are equitably distributed.

The sand itself remains inert, or only at the highest temperatures submits to incipient vitrifaction and fuses slightly at the surfaces with the clay. Its purpose is that of a diluent used to secure economy, strength, and symmetry. The mud from the pits is forced downwards through the body of the machine by a screw movement into a form of six moulds. This form is shoved out automatically and an empty form inserted by hand. The bottoms of the moulds are not tight, but admit air through narrow slits, so that the green brick can be easily dumped. A very fine moulding sand is dusted over the inside of the moulds after occasionally thrusting them into water, and before inserting them into the machine. This gives a finish to the surfaces of the brick, and also assists their rejection from the moulds. Coloring matter is sometimes inserted in this sand. After removal from the machine the tops of the moulds are struck off by hand, the forms placed upon light trucks, wheeled to the drying yards and dumped.

The drying yard consists of a plain surface, faced with a few inches of clay at the beginning of each season and kept well rolled. Occasionally the yard is covered with a succession of low, peaked roofs, supported by rows of posts, each side of the roof being divided into five feet battens, which can be closed or opened on trunnions like ordinary window-blinds, according to the state of the weather. Gutters carry off the rain. The advantages of a covered yard are self-evident, and yet few are constructed on account of the expense. Later in the day the bricks are turned on their sides and spatted to make their edges straight. In the afternoon they are gathered up and packed in rows three to four feet high and one brick wide. Saddles, consisting of two

12-inch boards nailed together at the edges, are placed over the bricks as a protection against the weather, and battens can be laid against the sides if bad weather is apprehended. They remain in hack from one and a half to four days, as atmospheric conditions may favor drying. They are then wheeled to the kiln and set up for burning. In the course of a season many green bricks are damaged by rain, and the loss is sometimes serious.

The kilns are usually built entirely of the green brick from the hacks, and are set up under long roughly built sheds at the end of the yards, and almost always run parallel to and within a few feet of the river. The two lines of heavy roof posts support in part the sides of the kilns, and to prevent accidents from the swelling of the brick during ignition the opposite posts are clamped together by bands of iron. On this account the kilns are usually referred to as clamp kilns.

Three hundred thousand to one million bricks are built edgewise into the kiln, allowing thirty-five to forty thousand to an arch. The kilns are about fifty bricks high, and thirty-six feet wide at the base, built with a very slight batter.

The bricks are set crossing each other, three on three, allowing vents ¼ to ⅜-inch for the heat to pass through. At intervals of about three feet at the base of the kilns, and extending through them from side to side, small pointed arch openings are built thirty inches high and sixteen inches span. Cord wood for burning is here introduced, and is supported on a brick hearth. The ends of the kilns are cushioned with moulding sand held in place by battens. By this means more of the heat is retained, and the sand is dried properly for dusting the moulds.

The sides of the kiln are daubed with clay, and slow fires started up under the arches. Drying off or water smoking, as it is termed, is carried on from thirty-six to thirty-eight hours. The arches on one side are then closed, and the fires driven diagonally through the kiln at a temperature sufficient to produce a white heat in the lower inside tiers of brick, which is gradually carried up to the top and opposite side. Then the process is reversed, with similar results.

The arches on both sides of the kiln are now fired, and this process of cross burning is carried to its conclusion. The whole operation takes about a week, after which the kiln is allowed to cool down, requiring another week. This part of the manufacture is the most critical and skillful of all the stages, and is intrusted to men of experience, who command high wages. It is a rule of thumb process throughout. The kiln, fifty bricks high, will sink from two inches to six inches in burning. A gauge along the side measures this settlement, and gives valuable information to the burner as to what progress has been made. The burner must regulate the intensity and direction of his fires entirely by the drafts at the arch openings. Barometric changes, changes of temperature and the wind have to be taken into consideration and guarded against.

As a matter of course bad burns occasionally occur; the arch brick are over-burnt and the outside brick under-burnt. This constant loss is a great drain on the industry, and also tends to deteriorate the quality, as it is the general custom to work the greater part of these poorer bricks off by inserting them among the good ones. Brick-makers have estimated that by the present process one-twentieth of the kiln turns out pale brick and one-twelfth arch brick. About five to six cords of wood, at an average cost of six dollars per cord, are required to burn forty thousand bricks.

The chemistry of burning may be roughly described as follows:

At a temperature of 100 degrees C., the water held in mechanical suspension is driven off. That held in chemical combination is then expelled at a temperature below red heat. At about red heat the decomposition of carbonates, if present, and the combustion of organic matter takes place. This is followed by a more intimate combination between the bases (iron, alumina, lime, and the alkalies) and the silica. This last process is known as vitrifaction.

If carried to a completion glass would be the result, but in practice vitrifaction is only carried to an incipient stage. The fusibility of the brick is increased by the presence of iron and the alkalies, and in a general way, lime, alumina and silica tend to diminish the fusibility.

The power of clay to recombine with water is, according to Bischoff, permanently lost at a temperature of 660 degrees Fahr.

In connection with the chemistry of brick-making, I would remark that the generally accepted explanations of the efflorescence which frequently appears on the surfaces of brick walls is that it is due to the presence of sulphates, nitrates, and chlorides of magnesia, potash and soda in the bricks or mortar. These are highly soluble compounds, and in wet weather are brought to the surface in solution and there precipitated.

BRICK MANUFACTURE NEAR CHICAGO.

By D. V. Purington.

Read April 18th, 1888.

In complying with your request for a brief description of the methods in use by the Purington-Kimbell Brick Company for making brick, I wish it distinctly understood that the Company makes no claim that these methods are original, or that they are exclusively their own.

There are several other firms who have adopted the same process, some of whom have more expensive plants, and some of whose yards excel ours in convenience of arrangement. I do feel, however, that I have the right to lay claim to being the pioneer in the use of the Chambers stiff mud machine, which has achieved so complete a success in Chicago. The first machine of this kind was erected by Messrs. Purington & Kimbell, the predecessors of this Company, in the early spring of 1882.

It was placed on a yard that the previous year had operated seven horse-power machines of the kind so generally used along the Hudson River. The clay used was dredged from the Chicago River, and one season clearly demonstrated the impracticability of its use on the Chambers machine. Taken as it was from the water, it required at least a year to dry out sufficiently to be available. The experiment was carried far enough, however, to prove that the hard, tenacious, blue clay which underlies our whole city, could be advantageously worked in its normal condition.

In June, 1882, Messrs. Purington & Kimbell secured another location on the banks of the Illinois and Michigan Canal, and located a second machine, designing to use the clay that had been dredged from the canal twenty-five years before. From its long exposure this clay was peculiarly adapted to the machine, and in the fall of 1882, the first machine, with engine, boilers, dryers, etc., was removed to the canal bank.

These two machines, one with dryer and one with out-door drying, made in 1883, 1884 and 1885, forty-six millions of brick. The maximum was ten millions on the machine with dryer and six millions five hundred thousand on the out-door yard. In the spring of 1883, this Company was incorporated and purchased the interest of Messrs. Purington & Kimbell, and, the clay becoming exhausted, purchased 47 acres of ground on the Rock Island Railroad, 14 miles from Chicago, and in the spring of 1886 erected thereon the works you have asked me to de-

scribe. The wisdom of going so far away from the city and endeavoring to compete has been clearly shown by the fact that the Company are able to deliver brick by rail to Chicago, and by teams to the building at a less cost than they had been able to do it from the yard in the city limits. The railroad company named the new station "Purington," and hereafter in this letter the new location will be known by that name. The clay here differs somewhat from that at or immediately around Chicago. It is much freer from limestone pebbles, and less of the consistency of india rubber, but is very hard, although slightly granulated.

For the first six months it was obtained by the use of pick and spade. It was found impossible to secure eleven men who could mine and load sufficient clay for forty-five thousand brick in a day of ten hours. As the season advanced, and the bank became dryer and harder, dynamite was freely used to assist in "getting a fall of the bank." In July of that year our bills for dynamite amounted to $85, and our average day's work less than we had made since the introduction of the Chambers, and we came to the conclusion that unless some more economical plan was devised, the Company would go the way of the dynamite.

Correspondence was opened with the manufacturers of steam shovels, and a contract made for one. At this point we committed the blunder that has been the bane of so many brick-makers, viz.: of trying to economize by getting machinery too light for its work. The expert who knew just what we needed, insisted that a No. 2 was ample for our wants. Four weeks of worry and bother decided that we had saved at the spigot and lost at the bung, and we were glad to make the best terms we could in exchanging for a larger one. This one was built with a dipper intended to hold 1½ yards, but, on our suggestion, was changed for a 1-cubic yard size. It requires 2 yards of clay, measured as dug, in the cars, to make one thousand brick.

Our shovel will easily dig enough for two hundred and twenty-five thousand brick in ten hours, inclusive of time consumed in moving, etc.

The dipper cuts from 4 to 5 inches in depth, 3 feet in width and 25 feet from bottom to top. This cut will ordinarily fill the dipper with clay, thoroughly mixed, cut in small pieces, and the two yards are taken from the bank and placed in the car in less than one minute's time. The cars are drawn from the shovel to the turn-table, a distance varying from 100 to 700 feet, by horses. Until the present year, our cars have been of the style in general use by railroad contractors, a box holding 2 yards placed on a half circle for a dumping rocker. The entire weight and strain comes upon one point, a line drawn lengthwise through the center of the car. I have found in dumping from the steam shovel, or in drawing these cars over an uneven track, that there was a great liability to breakage. I have now adopted the plan of dumping or tipping the track. The frame-work of my track is made of oak, 4 inches by

6 inches in size. Under this frame is placed a shaft 3 inches in diameter, with three bearings in each length of 16 feet, with the car fastened securely to the track. The operation of emptying the clay from the car is simple, and it is almost impossible to break anything. Under the old system (Cockrell) one man was kept steadily employed repairing cars. The cars are drawn up by a hoistway from the turn-table to the machine house.

The contents of the cars are dumped upon a platform, below which stand two Cockrell pulverizers, one for each brick machine. These pulverizers have never—and probably will never—come into general use, for the reason that so few clays can be successfully worked by them. With us they seem to fill the bill exactly. The object of the machine is to tear the clay to pieces, by a sort of whittling, its chips resembling in shape and condition those obtained in sharpening a lead pencil. It consists of a hollow vertical cylinder, at the bottom of which is a revolving horizontal disk, moved by a vertical shaft, connected above to the motive power. In the horizontal disk are set a number of knives, in the same manner as the knives of a plane, but with the cutting edges up. The slots in the disk in which the knives are set are also similar to the openings in a reversed plane. Underneath the machine is a belt conveyor. The top of the cylinder is on the level of the floor on which the clay is dumped.

It is the work of two men to shovel the clay from the floor into the cylinder when the disk is revolving two hundred and fifty times in a minute. The idea is to plane the clay in chips, pass it through the slots, and deposit it on the belt or elevator. It is then carried to the hopper over the brick machine. Around this hopper is a platform on which stands a boy, whose place it is to see that the hopper does not clog, and to add what water is necessary.

The brick machine is in charge of one man, who should be a tolerably good machinist, as well as a careful man of good judgment. The bricks leave the machine on the flat, but are immediately edged automatically. Three boys, from fourteen to sixteen years of age, take the brick from the belt and put them upon an iron car, each car containing five hundred and forty bricks. These cars are then taken by a man and run into the tunnels to dry.

There is nothing new or original about these tunnels, unless it is their length, 94 feet, and the use of an exhaust fan instead of a stack to remove the steam. Eleven tunnels, with a 30-inch fan for each two tunnels, will thoroughly dry fifty thousand brick in twenty-four hours. I am a decided advocate of artificial circulation to bring artificial drying to a point anywhere near perfection.

These tunnels should be filled before any are drawn out, and when a car is drawn it should be replaced by another. The grade is 1 inch to 10 feet. One man is sufficient to keep the fires in good condition, to draw out the brick when dry, remove ashes, etc.

In front of the storage tracks is a wide-guage track with a transfer car, on which the cars of dried brick are run to any portion of the 1 100 feet of kiln shed. Four men, who still retain the designation of brick wheelers, take the product of each machine to two setters. Our average for each machine in 1887 was forty-four thousand three hundred for each ten hours. I have given in detail the men actually engaged in making the brick and setting them in the kiln. As there are so many men whose work is divided on the whole four of our machines, I submit herewith the list and classification of our employees at Purington. I refrain from giving the wages paid, as that would vary in different localities and really does not enter into this comparison.

4 machine men.
4 " boys on platform.
8 men at pulverizer.
2 " hoisting machines.
1 engineer on steam shovel.
1 fireman "
1 craneman "
6 men in clay bank.
12 boys loading cars, handling cars, etc., with green brick.
4 men to put cars in dryer.
4 " fire dryers and take cars out.
4 " " " " at night.
24 " setting and wheeling.
1 engineer.
2 firemen.
1 carpenter.
1 blacksmith.
3 laborers.

83 Total.

Thus it will be seen that eighty-three men and boys make, dry and set in the kiln an average of one hundred and seventy-seven thousand two hundred brick per day.

From 1883 to 1885, with one machine used with dryers and one with out-door drying, our average was one hundred and sixty-seven days for the latter and two hundred and fifty-four for the former. The cost of brick dried artificially is less than those dried out of doors. The longer the season and the steadier the job the better the grade of men who will seek it. I have refrained from entering into a detailed description of the Chambers machine, for the reason that it is too well known to brick-makers to need it. This Company pays every two weeks, and during its existence has never missed a pay day and never had a strike. Since its location at Purington, no intoxicated man has ever been seen on or about its premises. Its relations with its employees are never strained;

and, while neither the Company nor men make any claims to foresight or sagacity peculiar to themselves, they do claim to have that perfection of an organization known as a union of the employer and employed. During the past year the Company erected a building 28x40 feet for the exclusive use of the men. They furnish heat and light, and the only restrictions placed upon the men are, that it shall be closed at 10 P.M., shall be kept clean and orderly, and that no intoxicating liquors shall ever be taken into it.

From a portion of the above it may be inferred that the executive officers of the Company are fanatics on the temperance question. This is not the case, but they are fanatical on the intemperance question.

The question of burning brick with crude oil has engaged the serious consideration of this Company for a year past, although it is only three months since their first experiments were made. The developments thus far in this new branch of a science, so all important to the brick-maker, are too crude and new to warrant any extended remarks. All who have tried it agree that as a fuel it comes nearer perfection than any other they have tried or known of, except it be natural gas.

All who have looked into the matter at all agree that hot oil, hot steam and hot air are necessary. No two agree, as yet, on the necessary quantities of either or the proper method of mixing them. I have now burned six kilns or about two million one hundred thousand brick. Thus far we have not had a bad kiln, and my experience justifies me in saying that I feel much more certain of a good burn than I ever did with wood and coal. The cost of burning with us is 35 per cent. less with oil than with wood and coal, and with large kilns the cost of labor is much less; two men will easily handle a kiln of twenty arches. No cold air is admitted and the checked, cracked arch bricks resulting from such admission are avoided. It is a promising field for experiment, and within six months, if we meet with no drawbacks, I hope to be able to write and talk more intelligently in regard to it.

In reply to questions Mr. Purington said: "My drying tunnels are 36 inches wide by 48 inches in height, and the average amount of coke used during the past two years in drying brick in twenty-four hours has been one ton to fifteen thousand brick. This coke costs me f. o. b. cars at Purington, $5 55 per ton. The expense is about equal to anthracite coal at $6 25; but I prefer the coke for the reason that the gas in the coal is more destructive to the iron cars. I should, perhaps, have mentioned that I have a steam dryer that, with a few changes, I think will accomplish better results than the hot-air dryers. Of this, however, I prefer to write when I am satisfied what it will do. In a general way, let me say there are many clays that can be successfully dried with a steam heat that cannot be with heated air passed over or through a heavy fire. While I regret very much that my time is too fully occu-

pied to write as intelligently or exhaustively as the subject deserves, I desire to congratulate the progressive clay worker that a body like yours deems our avocation of sufficient importance to give it so much attention. I have given to it seventeen years of the best of my life, and feel that I, with others who have tried so hard to place this industry in its proper place among the mechanical arts, have reason to congratulate ourselves that we are in the future to have the active co-operation of your Society."

SLATE BRICKS.

By José R. Villalon, Jun. Am. Soc. C. E.

Read April 18th, 1888.

The manufacture of slate bricks is carried on throughout the year by the American Brick and Tile Company, at Phillipsburg, N. J. This company started work in 1886, and since then they have kept always busy, and it has been necessary to enlarge and improve its plant.

The material used in making the bricks is the rubbish from slate quarries, though all kinds of slate may not be suitable, as experiments have been made with slates from Massachusetts, which were not entirely satisfactory. The rubbish used in this manufactory is of two different kinds of slate from the quarries of the Old Bangor Slate Company, at Bangor Pa., whose chemical composition is as follows, from analysis furnished by the Old Bangor Slate Company.

	Clear.	Ribbon.
Silica	56.78	56.15
Alumina	17.38	13.90
Lime	4.14	5.17
Magnesia	3.15	2.81
Iron peroxide	6.50	7.46
Sulphur	0.89	2.22
Phosphoric acid	0.133	0.13
Water and carbonic acid	7.60	10.47
Alkalies and organic matter	3.427	1.69
	100.000	100.000

This shows an equivalent of iron of 4.54 and 5.22 per cent. respectivly.

The plant used until the end of the year 1887 had a capacity of twelve thousand bricks per day, about thirty men and boys being employed. The spalls, which have an average size of 8 x 6 x 2 inches, were thrown into a crusher, in which they were broken into sizes up to $\frac{5}{8}$ inch, and were then passed to a Carlin grinding pan, where the first grinding was done, and in which the pieces were reduced to $\frac{1}{4}$-inch or less in size; an elevator then took the ground slate to a J. T. Noye's rolling machine, which reduced it to a powder, which was made to pass through a screen of four hundred meshes per square inch; the grains which did not pass through this screen were returned to the rollers.

The process was similar to that used in the flour mills. From the screen the powder goes to a pug mill, where thirty-five gallons of water are added to each gross ton of powder. The pulp then went to the brick machine, consisting of a packer box, under which the mould is placed ready to receive the pulp; by means of a packer which is raised and lowered, the pulp is forced into the mould, the mould then comes from under the packer and is taken out and a new one put in its place under the feeder; the moulds used were double, that is, two bricks were moulded at a time; its capacity was sixty bricks per minute. The moulds were then placed upon an endless belt, which carried them to the drying-room, where they were taken off and put on a floor heated by steam to a temperature from 80 to 100 degrees Fahr. In this state they are called green common bricks. After remaining upon this floor for about two hours they are fit for the presses. These were common hand-presses, four in number; the pressure on a brick was about three tons and the capacity of each press three thousand bricks per day; only one brick was pressed at a time; the bricks were carefully handled with paddles and placed in the press mould, in which the pressure was directly applied. The bricks after having been pressed, are relaid on the floor and dried again for one hour; they are not left to dry too much for then they get brittle. The power required to operate all this machinery was 60 horse-power.

The alterations and improvements lately introduced in the plant are the following: The crusher is not removed, but the grinding apparatus is changed by taking out the Carlin grinding pan and the J. T. Noye's rolling machines, and putting in instead two Cyclone Pulverizers, which grind the slate very fine. These pulverizers are not yet in running order at the factory, but the results of some previous experiments show that they can pulverize about forty tons of crushed slate per day. There are three screens through which the pulverized slate passes; the first containing four hundred meshes per square inch; the second sixteen hundred, and the third twenty-three hundred and four meshes per square inch.

The second screen will be used in these works and will improve the brick considerably, as the finest powder obtained with the old plant was equivalent in fineness to that which now passes through the first screen. The finer the powder, the more water it will require.

Another improvement is the change of the brick machine to another of the same system but of larger dimensions, making six bricks at a time in one mould, and having a capacity for thirty-five thousand bricks per day of ten hours. The bricks will now be subjected to the same operations as in the old plant, with the advantage of using, besides, a steam press. For this press the bricks are laid on the table, from which they are automatically fed under the mould, which is raised and lowered by a cam motion. While the mould is down in place for pressing, a plunger

is raised from the bottom by means of another cam, which gives the brick about thirty tons pressure; the mould then raises and another brick is ready to be placed under the mould. It presses one brick at a time and has a capacity for twenty thousand bricks per day. The bricks after leaving this press are very hard, and can be handled without paddles. The steam and hand presses, and also the brick machines, are all manufactured by George Carnell, Philadelphia, Pa.

After the bricks have been pressed, they are called green pressed, until they are dried sufficiently to go in the kiln, when they are called dried pressed.

With this new plant it is expected to have a regular output of thirty-thousand bricks per day.

Another improvement on the plant will be the use of a drying kiln into which the bricks will be run on cars, on which they remain until sufficiently dry to go into the burning kiln. The drying kiln is used simply to increase the production, as the drying floor is not large enough.

The bricks after having been pressed and dried, are burnt in permanent kilns. Of these there are now three, and two more are to be built very soon. The largest kiln now in use is 44 x 30 feet in the plan and 24 feet high, including the height of the arches below, which is three feet; it has a capacity for two hundred thousand bricks; the other two are of smaller dimensions and hold one hundred and forty thousand and one hundred and twenty thousand bricks. The largest kiln is built with ten rows of permanent arches running from side to side of the kiln. The thickness of the wall of the kiln is 24 inches, and that of the wall of the arches is 13 inches; the arches have open spaces 2½ inches between them, and the rows of arches are 4 feet 2 inches distant from centers, the radius of the arches being 2 feet 2 inches.

The bricks are set in the kiln in the ordinary way. The fire is applied under the arches on both sides of the kiln. The bricks are burnt hard, at a temperature of white heat. The fuel used is large egg coal. A kiln of the dimensions above given consumes forty-five tons of coal for one burning, and the others in proportion to the surface exposed. It takes four days and four nights to burn a kiln out, and from three to four days to cool it. In cooling the kiln the fire is not smothered as for clay bricks, but left to extinguish itself naturally after the fuel has burned out. As slate brick do not settle to any extent while being burnt, the burner judges when the bricks are burnt enough by the color of the flame in the arches and the smoke given off at the top of the kiln.

The different kinds of bricks are, 1. salmon; 2. hard common; 3. pressed standard; 4. fine pressed; 5. paving brick, and 6. clinkers. The salmon are not pressed, and being placed nearest to the wall of the kiln they are not very hard. Their cost on car at the factory is $7.50 per thousand. Hard common are the same as salmon, but burnt harder, $9 per thousand. The cost of the other kinds is as follows:

Pressed brick leads from.....	$12 to $20	per thousand.
Paving " " "	$12 to $13	"
Clinker, or arch brick "	$8.50	"

These bricks measure 8½ x 4 x 2½ inches, and weigh five pounds each.

The slate brick have all the qualities of good ordinary brick; they are very hard, ring well with a clear sound; the texture is compact and homogeneous; the grain is fine and free from pebbles, and they rarely crack; their color varies from a light rose up to a Philadelphia-brick red, and is said to become deeper upon exposure to the weather. The slate brick does not shrink or change in shape when burnt, but keeps the same size and shape which it had when it was green. A circle can be formed of a certain number of squared bricks, and after these are burnt, they will form a perfect circle as before. This is a quality which has not been obtained with brick from clay.

Pavements made of these bricks are very fine; they present a smooth surface and do not hold the ice like other pavements, but, like slate, are cleansed of ice very easily.

Neither the moisture of the atmosphere nor the rain water is absorbed to any extent through slate brick; they "wet in" scarcely ¼ of an inch, leaving the rest of the wall dry, thus diminishing considerably the dampness of the buildings. The average absorption of water on immersion is only six ounces; hence the life is not taken from mortar, the setting is slower and the adhesion greater.

These bricks cut easily with the trowel and neither lose their color nor present the white discolorations of clay brick.

The crushing strength of these and Philadelphia brick, as ascertained by Mr. John Neagley at the Keystone Bridge Company's works was for slate brick $4\frac{1}{2} \times 8\frac{1}{2} = 35$ square inches in area.

Total, 255 500 pounds = 7 230 pounds per square inch.

For Philadelphia $4 \times 8\frac{5}{16} = 33.24$ square inches in area,

Total, 131 300 pounds = 3 950 pounds per square inch.

The flexure or bending strength, as determined by Mr. A. W. Stedman, Chief Engineer of the Lehigh Valley Railroad, is about 2 665 pounds.

Within the last year several large buildings in Bethlehem, Easton, Phillipsburg, etc., have been erected with these bricks, which have shown no signs of failure or deterioration. Eleven millions of brick from the slate of Western Pennsylvania were used in constructing the Pittsburgh and Western Railroad tunnel underneath the City of Pittsburgh, and are said to have been entirely satisfactory.

Letter from WALTER S. CHURCH, Esq., Special Assistant Engineer, transmitting tables.

NEW YORK, April 17th, 1888.

JOSÉ. R. VILLALON, Esq.,

DEAR SIR,—Herewith I mail, as per your request of April 15th, 1888, a copy of such tests as we have already procured of the porosity of the several brands of brick submitted to Messrs. Fairbairn & Co. The tests were made by their agent, Mr. N. O. Olson. They are given without endorsement, as we are not yet in condition to institute our own tests in corroboration.

NEW YORK, March 29th, 1888.

AQUEDUCT COMMISSIONERS,

GENTLEMEN,—Herewith please find sizes of bricks tested for you, also weight of same.

Lot A. 5 Pressed Bricks, sent by W. W. Wheeler, Line Inspector, Haverstraw, N. Y.

" B. 5 Slate Bricks, Phillipsburg, Pa.

" C. 5 Bricks, branded W. A. U., Haverstraw, N. Y.

" 41. 1 Brick, black coated.

Lot A. Size in Inches.				Weight.		Weight after Absorption.				Total Amount of Water Absorbed 24 hours.	
						20 Hours.		24 Hours.			
Test No.	Length.	Width.	Thick.	Lbs.	Oz.	Lbs.	Oz.	Lbs.	Oz.	Lbs.	Oz.
5 773	8 3/16	4 1/16	2 7/16	5	12 3/4	6	8	6	8	.....	11 1/4
5 774	8 3/16	4 1/16	2 1/2	5	14	6	4 1/2	6	4 1/2	.....	6 3/4
5 775	8 1/16	4 1/16	2 7/16	6	6 1/4	6	7 1/2	6	7 3/4	.....	1 1/2
5 776	8 1/4	4 1/16	2 7/16	5	12 3/4	6	5 1/2	6	5 1/2	.....	8 3/4
5 777	8 3/16	4 1/16	2 7/16	5	14 3/4	6	8 1/4	6	8 1/4	.....	9 1/2
Lot B.	rough brick.										
5 778	8 3/16	3 11/16	2 1/4	4	14 1/4	5	1 3/4	5	1 3/4	.....	3 1/2
5 779	8 1/4	3 11/16	2 1/4	4	15 1/4	5	2 3/4	5	2 3/4	.....	2 3/4
5 780	8 3/16	3 11/16	2 1/4	5	.....	5	9 1/2	5	9 1/2	.....	9 1/2
5 781	8 1/4	3 3/4	2 1/16	5	2	5	5 1/2	5	5 1/2	.....	3 1/2
5 782	8 1/16	3 13/16	2 3/16	4	13 1/4	5	7 1/4	5	7 1/2	.....	10 1/4
Lot C.	rough brick.										
5 783	8 3/16	3 3/4	2 1/2	4	9 1/2	.....	.....	5	4 3/4	.....	11 1/2
5 784	8 1/2	3 3/4	2 3/4	4	13 1/2	.....	.....	5	6 3/4	.....	8 3/4
5 785	8 1/4	3 11/16	2 7/16	4	12 3/4	.....	.....	5	5 3/4	.....	9
5 786	8 1/4	3 3/4	2 3/4	4	9	.....	.....	5	5	.....	12
5 787	8 1/4	3 11/16	2 7/16	4	9 1/2	.....	.....	5	4	.....	10 1/2
Lot 41.											
5 788	7 13/16	3 1/2	2 1/4	4	5 3/4	.....	.....	4	6 1/2	.....	1/2

Below please find the amount of pressure applied to each brick, also amount of water which passes through bricks, and the length of time under which the pressure was applied.

AMOUNT OF WATER PASSED THROUGH UNDER THE FOLLOWING PRESSURE.

Test No.	Time, Minutes.	15 lbs.	25 lbs.	30 lbs.	43 lbs.	45 lbs.	53 lbs.	55 lbs.	60 lbs.	75 lbs.	Total Amount. lbs.	oz.
5773	5	2¼ lbs.	.....	4¼ lbs.	.....	6½ lbs.	7½ lbs.	....	.....	.....	20	½
5774	3	20 oz.										
"	5	3½ lbs.	.....	7 lbs.	.....							
"	20	13 lbs.	.....	.....	.....	.....	.....	....	.....	.....	24	12
5775	5	2¾ lbs.	.....	6½ lbs.	6¾ lbs.	.....	.....	....	.....	.....	16	
5776	5	2 lbs. 2¾ oz.	.....	4 lbs. 13 oz.	.....	6¼ lbs.	.....	7 lbs	.....	.....	20	13
5777	5	2 lbs.	.....	4 lbs. 6 oz.	.....	5 lbs. 6 oz.	.....	....	.....	7½ lbs.	18	
5778	5	1 lb.	.....	.....	.....	2¼ lbs.	.....	....	3¾ lbs	4½ lbs.	11	
5779	5	1¼ lbs.	.....	.....	.....	3½ lbs.	.....	....	.....	4½ lbs.	8	14
5780	5	0	11¼ oz.	.....	.....	25½ oz.	.....	....	2¾ lbs	.....	4	1
5781	5	1 lb. ½ oz.	.....	.....	.....	4¼ lbs.	.....	....	.....	4½ lbs.		12½
5782	5	Specimen b	roke, fl	aw.								
5783	5	"	"	"								
5784	5	0	.....	.....	.....	8¼ oz.	.....	....	.....	24½ oz.	2	
5785	5	0	.....	.....	.....	7¼ oz.	.....	....	.....	22½ oz.	1	13½
5786	5	0	.....	.....	.....	5 oz.	.....	....	.....	9 oz.		14
5787	5	0	.....	.....	.....	10¾ oz.	.....	....	.....	19 oz.	1	13½
5788	5	0	.....	.....	.....	0	.....	....	.....	0	No leak	age, tight.

Size of hole in packing through which pressure was forced, 2 inches x 5¾ inches.

Yours very truly,

(Signed) N. O. OLSON.

NOTE ON BRICK-MAKING IN SINALOA, MEXICO.

By Senor Don Fran. Sosa y Avela, Professor of Civil Engineering in the Collegio Rosalis, Culiacan.

Read October 19th, 1887.

The earth chosen is an alluvian from the banks of rivers that does not contain too much sand, and experiments are necessary to determine the proper proportion of dung—horse or mule manure—that the bricks may not break when placed in the sun to dry.

After the preparation of a drying floor, which is leveled and covered with sand, a shallow pit is excavated three or four yards square, in which the clay and dung are wetted, mixed and trampled, until the mass becomes plastic, and in that state the mass is left till morning.

The force employed in moulding and stacking the bricks is divided as follows: four carry the tempered clay to the edge of the drying floor, where two men mould them, one turns the bricks so that they may dry evenly, two carry them to be burned, when two more stack them in kilns of from 20 000 to 30 000 bricks. The stacks, which are burned with wood, have the usual arches and are covered with a course of brick treated with sand.

The bricks in common use have the following names and sizes:

Adobe, sun-dried brick, 24 x 16 x 3½ inches.

The following are burned:

Adovon, 18 x 9 x 3 inches, the common size for house walls, etc.

Ladrillo, 9 x 4½ x 2½ inches, used for ovens, thin walls, etc.

Tejas arqueadas, 14 x 9 x ⅜, roof tile.

Lozeta, 10 x 10 x 2½ inches, paving tile.

The standard price of the Adovon is, in the district of Sinaloa, $8 per thousand; at Fuerte, $14; in Culiacan, $10; in Mazatlan, $18; and at the mines in the Sierra the price is often $30 per thousand, depending on the cost of wood and the convenience of the clay. When the water is pure the bricks then are of a very good quality; a veritable artificial stone.

The roof tile receives more care both in the fabrication and burning, which is done in square kilns with walls 8 to 9 feet high, the floors of which are constructed of arches to hold the combustibles. Not more than five courses of tiles are burned at one time, and they are handled with great care, as before burning they are fragile. The fire is increased gradually until the smoke, which at the first of the burning had settled on the walls of the kiln, is burned off and the tiles are vitrified, which is known by their becoming bright red. One thousand of these tile cost from $8 to $12, and are laid so as to cover a surface of 194 square feet, at a cost of five cents per square foot.

DISCUSSION.

D. V. PURINGTON.—Mr. Chairman and gentlemen, I did not know until within the last five minutes that this is what was expected of me. I was invited to come here to listen to the discussion of these and other papers by the Society; it is a little difficult for a man to discuss his own family in public. I hardly know where to begin or what to say, and I really think the better plan would be for those gentlemen who desire, to ask me any questions in regard to the paper that was read in New York.

I would like to say, however, that in my twenty years' experience in the manufacture of brick, there has not been a more pleasant or encouraging fact than that this Society has evidently taken hold of that art to which I have given so much of my time. There is no business that I know of that is in so crude a state as the manipulating and burning of clay, and there is no other so open to improvement, and nothing which, in my judgment, will take such strides in advancement during the next twenty years as this same art.

The paper which I wrote was one to which I could give very little attention, and it was a very crude paper. I simply endeavored to give the methods in general use in and around Chicago, and the processes in use there would hardly be applicable in any other locality. There are some developments in our manufacture that would be applicable to other places, but no two clays can be treated alike with the same results.

If anybody would indicate what is expected of me I would endeavor to comply, or if any one desires to ask any questions I will answer them to the best of my ability.

J. T. DODGE, M. Am. Soc. C. E.—I wish to present a question, which either Mr. Purington or some other gentleman may be able to throw some light upon. I want to ascertain whether there is such a thing as producing what might be called a concrete brick by the use of silica, salt and quartzite, or some other hard substance, and a proper clay, which possibly might be improved by the addition of earthy elements like salt, or something of that sort, to facilitate vitrification. That is one of the subjects that I have revolved in my mind, and it involves chemical considerations. I hope some member of the Society will be able to give some information. Mr. Purington's paper, I think, treats pretty much of the business processes, of the moulding and burning of brick.

Mr. PURINGTON.—I am interested in that.

Mr. DODGE.—Is there not a way of burning brick that would make a paving brick, which would serve in sidewalks or crosswalks? Samples of brick, made for paving purposes, are seen on the way from here down-town. The material is, I suppose, cemented by Portland cement; that, at least, is what I conclude.

G. H. BENZENBERG, M. Am. Soc. C. E.—If Mr. Dodge has reference to the walk across the Court House Square, that is compressed asphaltic brick.

Mr. PURINGTON.—There is being put upon the market in Chicago a brick, which is manufactured by what is known as the Myenbury Brick Company, for which they claim that it is exactly such a brick as Mr. Dodge is inquiring for. For instance, this brick can be written upon with pen and ink, and after the ink is dry you can take a cloth and wipe it off. Whether the process has been so far developed as to bring it to perfection I do not know. The first patent on the process, as I understand, covers the material put in to assist in vitrification.

N. M. EDWARDS, M. Am. Soc. C. E.—I would like to ask if sun-dried or air-dried brick, made here, are much used for interior walls. Whether they rely on such bricks as these for interior walls without burning?

Mr. PURINGTON.—I don't know; we never use them in this part of the country. I have seen them used in Mexico for exterior walls.

J. B. FRANCIS, Past President Am. Soc. C. E.—Is not the way the Romans made brick a lost art? They made bricks over two thousand years ago, and we find them now, sticking out of their masonry, and they seem to be perfect. Is this a lost art?

Mr. PURINGTON.—No, sir, it is not. The manner of making brick for the last three hundred years, with the exception of perhaps the last twenty years, has hardly been improved on. One reason that these bricks have stood so long may be from the superiority of the clay.

Mr. FRANCIS.—The clay in various countries is very likely to differ.

Mr. PURINGTON.—The bricks made in Philadelphia and in Milwaukee are entirely different; one will sustain about the same crushing weight as the other, however.

Mr. EDWARDS.—Are bricks found in cold climates in a well preserved condition?

JOHN BOGART, M. Am. Soc. C. E.—There are in good condition in England brick walls made by the Romans, and that is a pretty cold climate.

Mr. EDWARDS.—Will vitrified brick do the same thing?

Mr. PURINGTON.—Yes, sir. There are some clays which, if thoroughly prepared before being made into brick and burned well, would stand as long as those made by the Romans.

A. DEMPSTER, M. Am. Soc. C. E.—Will the Chicago bricks stand two thousand years?

Mr. PURINGTON.—They will stand as long as any others; but that is a question that I can answer better two thousand years from now.

Mr. DODGE.—A clay which I have seen at Duluth, from which they make bricks, has in it pebbles of limestone, and they have been very much troubled to get rid of them, so they have crushed them, reducing them to smaller pieces. One building to which my attention was called, had been built with bricks in which the limestone pebbles were crushed so small that no difficulty arising from the pebbles was feared, yet the brick in that building were saturated with water from the gutters, from the top to the bottom of the building, and were totally ruined. The brick were made with a machine, and through every brick were two holes; possibly any brick-maker may know what machine it is. The bricks, when saturated with water, break and chip or scale off on a nearly vertical plane; I believe that when they lie either as headers or stretchers, they break off parallel to the face of the building. Another lot of these bricks was saturated by water, and they did the same thing; they parted in vertical chips, extending nearly across the bricks, and in thickness from one-eighth to one-quarter of an inch; it looks pretty bad. I asked the brick-maker about it, and his opinion was that it was due to the manner of moulding. I asked him whether the lime had not something to do with it, but he said he thought not. This is a very serious trouble there. These bricks cannot be used on the face of a building if the water gets to them. In some of the buildings the brick have stood for two seasons without the water getting to them, but in the third winter, when they got snowed on, they scaled off and went to pieces; it is only a matter of two or three seasons when these bricks will be entirely gone. I would like the opinion of experienced men on this question, whether this is due to the moulding or to the effect of the lime.

Mr. PURINGTON.—There may be two or three reasons. I think it is a great mistake to grind up lime pebbles, because a very small piece of lime, as large as a pin head, if it slacks at the proper time, will break up almost any brick; therefore the pebbles should be taken out whole or left in whole.

In the process of moulding referred to by Mr. Dodge, the clay from which the brick are made is pushed out from the side and the brick are cut off with a wire, lengthwise; I can compare the strength of that brick to nothing better than cutting off a piece of board lengthwise or crosswise; if you cut off a piece of clay across the end of it you have the same result that you would have in cutting off a piece of board, that is, it is across the grain, and, the fibre running that way, the water gets in and freezes there and cracks it off.

There is still another reason that would bring about the same results. The clay may be so nearly a pure clay, so rich, that in that process of making brick you cannot put sufficient sand in it to make it a durable brick when vitrified.

J. B. JOHNSON, M. Am. Soc. C. E.—Can Mr. Dodge state what per cent. of absorption those bricks are capable of.

Mr. DODGE.—It must be large, but I could not say exactly.

ROBERT MOORE, M. Am. Soc. C. E.—There is another phenomenon in a different climate which I would like to have somebody explain, and that is the failure of brick walls which one so often sees in New Orleans. It is very common to see brick walls near the ground that have scaled off an inch or two in depth. They seem to be a soft brick, but whether it is due to a certain defect of the clay, or of their manufacture, or what is the cause, I do not know.

Mr. PURINGTON.—The probability is that that class of brick was never burnt or vitrified, and no brick should ever be put where moisture from the ground can be absorbed unless it is burnt. The probability is that the quality of the clay from which this brick was made was such that it could not be burnt to vitrification. We have near Chicago a clay that it is impossible to vitrify; if mixed with this sort of clay the brick never vitrifies, and it cannot be burnt so that it is safe to use for foundations or in fire walls.

Mr. MOORE.—The brick I speak of are in New Orleans.

Mr. PURINGTON.—Nearly all the brick in New Orleans are made from alluvial deposits in the Mississippi River, and there is really very little clay in this, it is almost all a loam or fine sand that is washed down the river. I don't think I ever saw a real vitrified brick in New Orleans; they would not stand our northern climate at all.

Mr. DODGE.—I would ask Mr. Purington whether the bricks which are used in Chicago for outside work—by which I mean common bricks, not pressed—whether the outside bricks in Chicago and Milwaukee are really vitrified; whether vitrification really takes place?

Mr. PURINGTON.—About one-third of them are, and ordinarily these are sold to the city for sewage bricks, so that very few get into the buildings. A little secret of the trade that I hope won't be given away.

Mr. BENZENBERG.—I don't know whether Mr. Purington refers to Chicago or Milwaukee, but as to the Milwaukee brick, the brick-makers here generally furnish for sewers a still harder burned brick than that used for buildings; they select the better burned bricks for the buildings, but the common run of brick, the harder burned, are used here for sewers.

Mr. PURINGTON.—The brick made there are vitrified and are very hard; those that go into the sewers are just as good as the others, but, because they are much harder, they are apt to be out of shape.

Mr. DODGE.—Are the bricks that we find laid in the sidewalks here, and which seem to have large pebbles in them, made specially for that purpose, or were they selected from the kiln?

Mr. PURINGTON.—I know nothing about Milwaukee brick.

Mr. BENZENBERG.—I am sorry that we have not some of our Milwaukee brick-makers here. I am but very little acquainted with the art of brick-making. The brick used here for sidewalk purposes, as I understand it, is the less expensive, ordinary common brick.

Mr. PURINGTON.—I would like to say that we have an association of those interested in brick manufacture of some three hundred members, and so far, we have no membership at all from Milwaukee; we have tried very hard to get the Milwaukee brick-makers interested, but have not succeeded. The National Association of Brick-makers meet once a year, and if any of you are disposed to and have the time, we should be glad to have you attend our next meeting at Memphis, Tenn., November 14th and 15th, and will try to get as much out of you as you have out of me.

H. B. SEAMAN, M. Am. Soc. C. E.—I would like to ask if the average sustaining power of brick is 2 000 pounds, from 1 800 to 2 300 pounds; is there any means by which brick may be manufactured from the same clay to resist, say 10 000 or 15 000 pounds to the square inch?

Mr. PURINGTON.—I would say in reply, that the poorest brick that we sell in Chicago would stand 14 000.

Mr. SEAMAN.—The reason I ask is that there were experiments made in Cincinnati and Philadelphia, where the limit of strength was from 10 000 to 20 000 pounds, although General Greene's experiments attained an average result of 2 700 pounds.*

Mr. PURINGTON.—I have not gone into the subject in that way.

Mr. EDWARDS.—I understand that some years ago extensive experiments were made upon brick made in Milwaukee.

C. L. GATES., M. Am. Soc. C. E.—The experiments that were made at that time gave results of crushing stresses of from about 800 to 5 000 pounds to the square inch; these experiments were made on small sized brick, a cube perhaps an inch square.

Mr. FRANCIS.—Could not a rough, well-burned brick be used more extensively for masonry. I visited a few years ago a place where they were building walls of very rough brick, laid in hydraulic mortar. The bricks were used as being the cheapest material.

Professor I. O. BAKER.—In this discussion it is necessary to bear in mind that the quality of brick has been very much improved within the past few years. For example, one of the most intelligent and prominent brick manufacturers of Central Illinois told me recently that brick as good as the best made ten years ago, could not now be sold at any price, because they were not good enough. I am a regular subscriber to a

* Trans. 1873: Vol. II., p. 185.—Notes on the Resistence of Bricks to a Crushing Force.

journal devoted to the brick manufacturing industry, and have concluded from reading its pages that there has been equally great improvement all over the country. Of course the quality of the brick varies with the locality, owing to differences between the clays and in the mode of manufacture. I desire to call attention to the fact that the quality of the ordinary run of brick is very much better now than a few years ago, and I believe that brick could be advantageously employed by engineers much more than at present, particularly where good stone is not abundant.

According to Trautwine's Pocket Book, the crushing strength of brick varies from 560 to 4 200 pounds per square inch. Rankine says the crushing strength of "strong red brick" is 1 100 pounds per square inch. General Greene's experiments, made in 1860, gave from 1 700 to 3 400 pounds per square inch. The strength of the brick tested at the Watertown Arsenal during 1882–85 varies between 5 500 and 22 300 pounds per square inch; different lots averaging 8 000, 10 000, 11 500, 14 000, and 18 000 respectively. According to Rankine, a good brick, when set on end, should require at least 1 100 pounds per square inch to crush it. Some brick tested on end at Watertown gave an average strength of 7 600, 10 500, and 14 400 pounds per square inch for "light red, medium red, and dark red brick," respectively. The Watertown brick appears to have been such as are employed in actual construction. I have seen the brick used in the Pension Building at Washington, which stood 8 000 pounds per square inch as above, and should judge that what is known in Central Illinois as paving brick, is very much stronger, probably two or three times as great. Brick that will stand the service in pavements, as successfully as they have done in numerous places all over the country, are sufficiently strong and durable for use in any masonry structure.

The general opinion is that brick-work is in every way inferior to stone masonry. This belief may have been well founded when brick was made wholly by hand by inexpert operatives, and imperfectly burned in the old-time kilns, the product being then generally poor; but things have changed, and since the manufacture of brick has become a business, conducted on a large scale by enterprising men, with the aid of a variety of machines and improved kilns, the product is more regular in size and quality and in every way better than formerly. I believe that there are many engineering structures in which brick could be profitably employed instead of stone; as, for example, the walls of box-culverts, cattle-guards, etc., and the less important bridge piers and abutments, particularly of highway bridges. The correct rule for such structures is to construct them of as large stones as possible; but if they are built of good brick, laid in strong cement mortar, they will be more nearly monolithic and better than they generally are.

Brick-work is preferable to stone masonry in several respects, as fol-

lows: 1. In many localities brick is cheaper than stone, since the former can be made near by, while the latter must be shipped. 2. As brick can be laid by less skillful masons than stone, it costs less to lay it. 3. Brick is more easily handled than stone, and can be laid without any hoisting apparatus. 4. Brick requires less fitting at corners and openings. 5. Brick masonry is less liable to great weakness through inaccurate dressing or bedding. 6. Brick-work resists fire better than limestone, granite, or marble; sandstone is the only variety of stone that can compare with brick in power to resist fire. 7. Good brick stands the effect of weathering and of the acids in the atmosphere better than sandstones, and in durability even approaches some of the harder stones. 8. All masonry fails when the mortar in its joints disintegrates or becomes dislodged; therefore, brick masonry will endure the vicisitudes of the weather as well as stone masonry, or even better, since the former usually has thinner joints.

The heaviest pressure borne by any masonry structure—the towers of the Brooklyn Bridge—is a little less than 400 pounds per square inch (28 tons per square foot); while experiments made at Watertown showed the average strength of brick piers laid with mortar composed of one part Rosendale cement and two parts sand was 1 972 pounds per square inch (140 tons per square foot), and with a mortar composed of one part Portland cement and two parts of sand was 2 544 pounds per square inch (180 tons per square foot). The piers were built by a common mason with the same care as that usually given to ordinary masonry. If brick masonry of the quality of last-mentioned piers were substituted for the granite masonry of the towers of the Brooklyn Bridge the factor of safety would still be about 6¼; and if substitutedf or the limestone masonry, the factor would be 20.

In conclusion, it may be well to state that I have no financial interest—even the most remote—in the brick industry.

J. B. JOHNSON, M. Am. Soc. C. E.—I made some timea go three sets of tests, 50 bricks in each test, with St. Louis brick of three kinds of manufacture, viz.: hydraulic pressed, mechanical pressed, and hammer-blow pressed brick. Our St. Louis brick are of a very good quality. These tests were made for absorption, cross-breaking, testing endwise, and testing flatwise with 4 half bricks made into a column with neat Portland cement mortar joints, which had stood for some three weeks. The single flatwise test would run up to about 8 000 or 10 000 pounds per square inch, but I consider it absolutely worth less for any commercial purpose. The endwise test was, in each case, from 20 to 50 per cent. greater than when 4 half bricks were made into a small column and tested. The test of these 4 half bricks laid into a column, I consider is certainly more than the strength of any wall or pier would be, made of the same brick, but that test was 25 per cent. less than the test endwise, and the endwise test gave only about one-half

or one-third the strength of the single flat test. So that when tables are given of tests and we simply see that experiments have been made and the brick stood so much, without knowing how it was tested, we can make no comparison between any two, unless we know all the circumstances. Why the Watertown Arsenal should continue to test in this way is a mystery to me; the tests are absolutely worthless, and the practice should be abandoned and no report should go out of a test made in that way; the method is such that it can only mislead.

No crushing test should ever be made on a specimen of less height than its least lateral dimension. In fact the only justification that can be given for the cubical form is that such has been the almost universal practice, and for purposes of comparison it is necessary to continue it. A really fair test in crushing cannot be obtained on a specimen of less height than 1½ times the least lateral dimension, and a ratio of 2 to 1 is preferable. All granular or amorphous solids fail in compression by shearing along diagonal planes, and unless the height is sufficient to allow these shearing stresses to act freely, then an abnormal strength is obtained. Therefore, if a single brick is to be tested by crushing, I think the endwise test can alone determine its normal strength. The fact that this is not the direction of its loading, either in manufacture or use, is, I believe, no objection. Bricks seem to have about equal strength in all directions.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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(Vol. XVIII.—June, 1888.)

A NOVEL APPLICATION OF THE POLAR PLANIMETER.

By CHARLES E. EMERY, M. Am. Soc. C. E.

READ JULY 5TH, 1886.

The steam meter designed by the writer for the use of the New York Steam Company, automatically registers upon a strip of paper, moved longitudinally by clock work, at the rate of ½-inch per hour. A base line is formed upon the paper by a stationary pencil, and a movable pencil operated by the meter traces a diagram, the height of which above the base line at any point is proportioned to the weight of steam flowing through the meter at the corresponding time, less a constant difference in elevation on diagram, due to the lap of the meter valve. The tracks of the two pencils coincide when no steam is used. The diagram commences when steam is turned on, as is shown by an abrupt line at right angles to the base line. While a supply is being delivered the height of the diagram varies with the demand, and when steam is shut off the movable pencil falls abruptly to the base line. This form of meter was settled upon after considerable experiment as being the only one which would reliably measure a fluid moving at a

velocity of 80 to 100 feet a second, and finally came into use to the exclusion of all other forms. The diagrams were especially advantageous in enabling the wasteful use of steam out of business hours to be detected, but the integration of the several thousand feet of diagrams accruing every month involved serious labor, and it was seen that some special apparatus was desirable to facilitate the work. The use of the ordinary planimeter saved considerable time in the integrations as compared with any method of measurements by means of ordinates, and the attention of the writer was directed to designing special planimeters and acompanying apparatus which would enable the work to be performed still more rapidly. Some difficulties, which had been experienced with one of the original Amsler instruments, and an erroneous statement in regard to the principles of the device, published in a circular shortly after the instrument was introduced, led the writer to undertake a new investigation of the principles involved in the operation of the instrument, which investigation was published, under the title of "The Polar Planimeter," in Vol. VI, Trans. Am. Soc. Mech. Eng'rs. Previous investigations in the same direction were not lacking, but the writers treated the subject generally as a mathematical problem or puzzle, without formulating practical rules to enable the instrument to be properly constructed or adjusted when out of order.

It is believed that it will be of interest here to reproduce for reference a summary of the governing proportions and general principles which affect the action of the instrument.

All polar planimeters are provided at one end of the main arm with a "tracing point," at the other end with a joint, guided either in a groove or by a radius arm, which joint we will call the "hinge," and there is pivoted in bearings on the arm a "recording wheel," which is usually placed between the tracer and hinge, or in the line of the two beyond the latter.

It can readily be shown:

First.—That if the "hinge" end of the arm be permitted to move in a fixed path in any direction, it is necessary only that it be returned by the same path; that is, the "hinge" end may be guided either by a radius arm or by a groove either straight or curved.

Second.—When the angle of the main arm is changed less than 360 degrees and the tracer is moved backward to the original position, the axis of the roller should be parallel to a line connecting the tracing

point and hinge, and the only proportions affecting the result are the length of main arm between tracer and hinge and the diameter of the recording wheel. If N = length of main arm, from tracer to hinge, D = diameter of recording wheel, and J = number of divisions on the wheel, each representing a unit of area.

$$(a)\ ND = \frac{J}{\pi};$$

or, when $J = 10$, as is customary.

$$(b)\ D = \frac{3.183}{N}$$

$$(c)\ N = \frac{3.183}{D}$$

Third.—When one end of the main arm is guided by a polar arm and the fixed point or pole is located within the figure to be measured, it is essential that the tracer, the hinge and the axis of the wheel be constructed in the same straight line, and there is to be added to the area indicated a quantity constant for the particular proportions of the instrument. If N = length of main arm, from tracer to hinge, as before, R = the distance of bearing point of recording wheel from hinge, P = the length of the polar arm, and A = the area to be added.

$$(d)\ A = \pi\,(P^2 + N^2 \pm 2\,NR).$$

The minus sign before the last term in parenthesis applies when the tracer and wheel are both constructed on the same side of hinge, and the plus sign when they are on opposite sides.

In designing special apparatus for integrating the meter charts above referred to, the shape of the planimeter was adapted to the work, and the hinge end guided in a groove in the edge of a steel rule mounted on a special table, provided with devices to depress or elevate the rule and clamp or release the diagram paper as desired. In the drawings Plates LXXIII and LXXIV. Fig. 1, is a plan view of the complete apparatus; Fig. 2, an edge view, and Fig. 3, a cross-section of the same. Fig. 4 is a plan view of the planimeter proper on an enlarged scale, and Fig. 5, a vertical elevation of the same. Figs. 6 and 7 show alternative cross-sections of the guide rule. In Figs. 4 and 5, n will be recognized as the tracing point, s as the hinge and l, the recording wheel of planimeter, the graduations being upon a smaller attached cylinder, M.

Formula (a) above, shows that the product of the length of the main

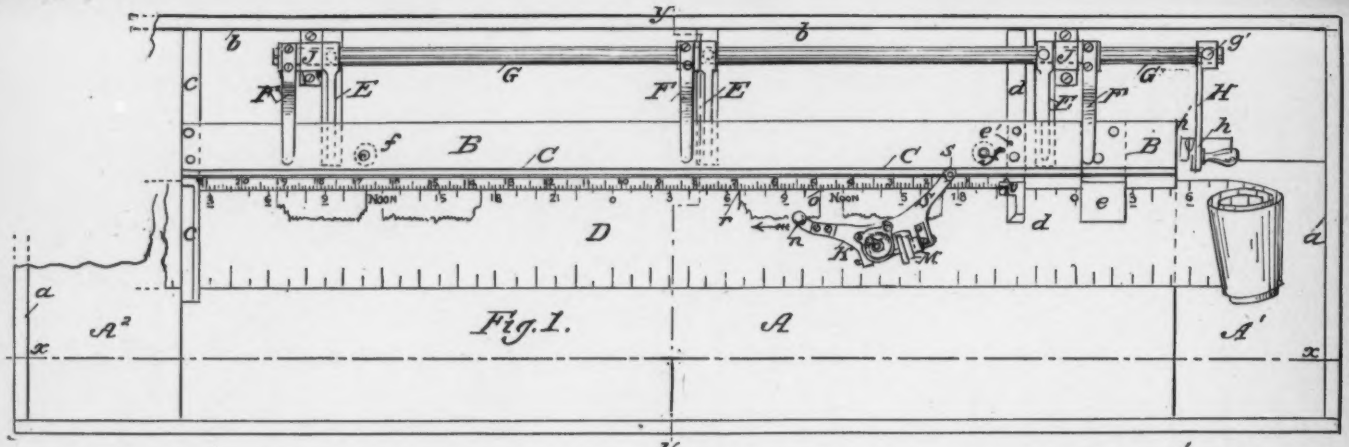

Fig. 1.

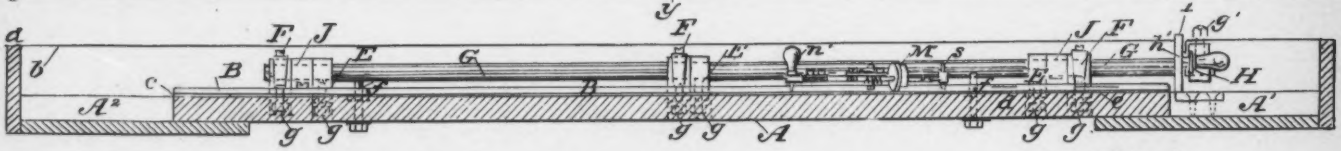

Fig 2.

Fig. 3.

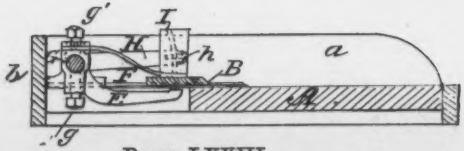

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PLATE LXXIII.

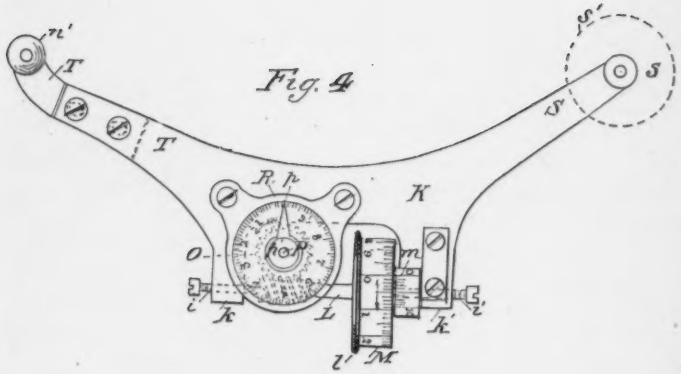

Fig. 4

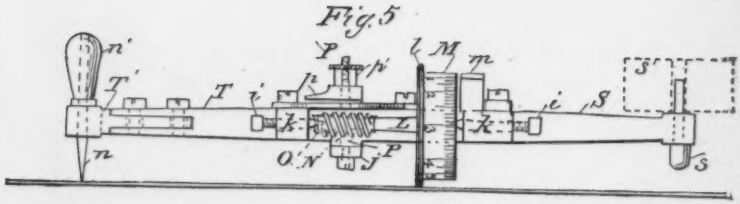

Fig. 5

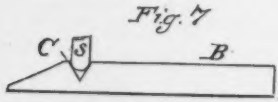

Fig. 7

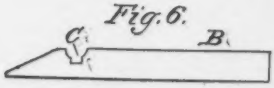

Fig. 6.

arm by the diameter of the recording wheel is a constant quantity, and as the diagrams to be integrated were less than 3 inches wide, by reducing the length of the arm between the tracing point, *n*, and the hinge, *s*, to 4 inches, the proper size of the recording wheel was increased nearly to .8 of an inch (exactly .79575 inch), which is much greater than in ordinary planimeters, and enabled the scale on the attached wheel, *M*, to be plainly read. The recording wheel was placed well at one side of the arm, so as to be at all times on the paper, and to give three points of bearing for the planimeter, so that it would rest securely. On the axle, *L*, of the recording wheel is a worm, *N*, which operates the worm-wheel shown, and moves the pointer, *p*, with one-tenth the velocity of the recording wheel. The handle, *n'*, over the tracing point is swiveled to facilitate its manipulation. It will be observed that the whole planimeter is, when in use, at the right, or under the right hand of the operator, so that the light upon the diagram comes freely to the tracing point without shadow from the hand. The stud, *s*, forming the hinge end of the planimeter is kept down by a weight, *s'*, as is customary.

The rule designated *B*, sets loosely over two guide-points, *f f*. The front edge is beveled. Just back of the edge is a groove, *C*, parallel therewith, to guide the hinge end of the planimeter, as shown in Figs. 6 and 7. This groove is made of V section or hemispherical, with the bottom removed to receive the hemispherical end of the stud, *s*, forming the hinge end of the planimeter arm. This form of the stud, *s*, with the groove shown enables universal motion about the point, *s*, when the planimeter is in use and when lifting the planimeter wheel from the paper. As shown in Fig. 1, the rule, *B*, is provided with rear arms, *c*, *d*, which merely touch the board to steady the rule as it is raised. On the front edge of the rule there are also the arms, *c*, *d* and *e*. The inner sides of the arms, *c* and *d*, form guide edges for the tracing point of planimeter at the extreme limits of motion. The distance between these edges is made 21 inches, corresponding to forty-two hours, so that the instrument has to be applied but four times for one week's record. The arm, *d*, is made short, so that the wheel of the planimeter will pass it when the tracing point is sliding along the edge of the main rule, *D*. The rule is extended to the right a distance equal to the length of the planimeter and, when the planimeter is not in use, the tracing point is lifted and carried back to the prick-punch mark, *e'*, in which operation the measuring wheel, *l*, of the planimeter rolls upon the projecting arm or

table, *e*, when, all three bearing points of the planimeter being upon the rule, the whole instrument is lifted as the rule is lifted.

The rule is lifted by the upturned ends of the three arms, *E*, fastened to a rock shaft, *G*, and is depressed by three springs, *F*, attached to the same shaft. The arm, *H*, on the end of shaft, *G*, is operated by the handle, *H*, to raise and depress the rule. Upon the inside of the arm, *H*, is a projecting piece which catches into notches in a bracket shown, whereby the rule may be held in an elevated position, free from the board upon which it ordinarily rests, so that the paper can be introduced beneath it. It will be observed that there are depressions at the ends of the main board forming shallow pockets, A^1, A^2. In operating the instrument, the roll of paper is introduced into the pocket, *A*, and drawn through under the rule, when it is raised as described. The handle, *H*, is then brought to mid position, when neither the springs, *F*, nor the arms, *E*, bear, and the weight of the rule simply rests on the paper, giving an opportunity to adjust the paper to bring the base line to the edge of the rule. The arm, *H*, is then depressed and locked down in a notch as described, so that the springs, *F*, bear firmly on the rule and clamp the paper in position.

It will be observed that there is a square projection at *v*, entering the corner where the projecting piece, *e*, meets the edge of the main rule. This is grooved on the top parallel with the two edges, and at the intersection a prick punch point made. The first operation after clamping the paper is to move the tracing point, *n*, from the prick punch point, *e*, to *v*, that referred to at the intersection. The recording wheel, *l*, is then revolved by hand to zero, and the tracing point operated to run around the figure from right to left, first following therefore the outer irregular edge of the diagram and being brought back along the edge of the rule. In case there are a series of short diagrams, the instrument may be started on either, but the whole can be integrated together by running from the ruler around each separately to the rule again, then along the rule to the next one, and around that in a similar manner, thus repeating, and finally returning to the place of beginning along the edge of the rule.

It will be observed that the edge of the rule is graduated to inches and tenths and, as the planimeter recording wheel is graduated for square inches, the mean height of the diagram, or the average mean height of the smaller diagrams, is obtained by simply dividing the area,

or the sum of the areas, by the length, or the sum of the lengths, as the case may be. In practice a constant quantity is deducted from the mean height thus obtained, to provide for the lap of the meter previously referred to, and the remainder multiplied by a factor applicable to the particular meter gives the total quantity of steam consumed for the time under consideration.

When the portion of the diagram between the arms, *c* and *d*, on the rule has been operated upon, the rule is lifted and the diagram moved from left to right readily, the base line readjusted to the edge of the rule, and the measuring operation repeated.

The rule, *d*, may readily be lifted off the pins, *ff*, and laid on any drawing and used to guide the planimeter to measure an irregular surface on such drawing. In this case, if the surface be a large one, it can be measured in a series of belts, each within the capacity of the instrument. The outlines of the belts can be conveniently distinguished by pencil lines and a ruler laid against the one in advance to guide the tracer accurately, and upon completing the circuit the guide ruler itself may be moved forward to the next boundary. In instruments designed for general use, the rule *B* may be made of any convenient length, and, of course, all the lateral arms, *c*, *d* and *e*, would be omitted.

The preliminary investigations made by the writer as to the principles of the instrument, enabled him to design the apparatus above described, complete, and ask for prices for its construction from drawings and descriptive specifications as confidently as if the work was of an established character. Three of the instruments, complete, have been made in accordance with the drawings by the Ashcroft Manufacturing Company, of Boston, Mass.,* for the New York Steam Company, and all operated from the first correctly and satisfactorily, saving for the particular work named more than one-half the time required with ordinary planimeters.

* Represented by Messrs. Manning, Maxwell & Moore, New York.